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Aquifer Disposal of CO_2 - Rich Gases

Phase 1

ALBERTA DEPARTMENT OF ENERGY

AQUIFER DISPOSAL OF CO_2-RICH GASES

MARCH, 1993

AQUIFER DISPOSAL OF CO_2-RICH GASES

Phase I

IN THE VICINITY OF THE SUNDANCE AND GENESEE POWER PLANTS

Injectivity, Chemical Reactions, and Proof of Concept

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TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

APPENDICES

(These are filed with the Alberta Department of Energy)

ACKNOWLEDGEMENT AND DISCLAIMER

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EXECUTIVE SUMMARY

1. Aquifers are Important Candidates for CO_2 Disposal

Currently there is considerable interest in using geological structures (salt domes, brines, coal beds, oil and gas reservoirs, or aquifers), the deep ocean or enhanced oil recovery as sinks for disposal of CO_2. In the short term, enhanced recovery projects can utilize CO_2 if these projects are near the CO_2 source. However in the longer term, deep aquifers appear to offer the best promise for accepting large quantities of waste gases. Their global distribution and their large *disposal volume* are appealing for disposal of waste fluids or gases, particularly from point emission sources. Carbon dioxide is an ideal candidate for aquifer disposal because of its high density and high solubility in water at the relatively high pressures which may be imposed in aquifers.

2. Aquifer Disposal Pipelines and Wells Small Part of Total CO_2 Disposal Cost

Aquifer disposal of CO_2 from a site in the Alberta (geologic) Basin containing over two-thirds of Alberta's coal-based electricity generation (i.e. Wabamun, Sundance, Keephills and Genesee power plants) was examined. A coal based power plant with 500 MW of net electricity output and a 30 year life (used as a base case) will generate close to 15,000 tons of CO_2 a day. The CO_2 would be injected as a liquid using a distribution system of 15 disposal wells, with each well accepting 1,000 tons per day. The analysis indicates that capture and compression facilities are the major disposal costs. The CO_2 transfer pipelines and disposal and monitoring well system will have a capital cost in the order of $2,200 per tonne per day of disposal capacity. However, the aquifer disposal system represents only a small portion of the overall CO_2 capture, purification and compression costs - capital and operating.

3. The Alberta Basin Aquifers Can Accept CO_2 Generated by 500 MW Plant

Over a 30 year period, 0.16 Gt (i.e. gigatons) of CO_2 would be produced from a 500MW coal-fired power plant. Carbonate (i.e. Wabamun) and siliciclastic (Lower Mannville) aquifers were identified in this study area in the Alberta Basin capable of accepting well above this quantity of CO_2. Modelling of injection into these aquifers concluded that disposal of 1000 tons/well of CO_2 was obtainable.

4. The Best CO_2 Traps are Mineral Traps

Concern about the stability of the long term capture of CO_2 has been addressed. Conventional wisdom has restricted the disposal of CO_2 to the subsurface where there are stratigraphic traps. In what we think is a novel approach, we advocate the consideration of mineral traps in aquifers. Modelling of geochemical reactions between CO_2-charged water and aquifer mineralogy clearly identified siliciclastic aquifers as capable of trapping large quantities of CO_2 by the precipitation of calcium-magnesium carbonate minerals. These conclusions are general and may be applied to any aquifer. These ideas were presented at the March 1993 IEA Carbon Dioxide Disposal Symposium at Oxford, England. The full context of the paper is contained in Appendix 11.5.2.

5. Aquifer Disposal should be Viewed from the Framework of a Sedimentary Basin

These mineral trapping reactions are kinetically very slow; but given the low regional flow rates (i.e. approximately 2 cm/year) and the large size of the Alberta Basin, the CO_2 would be hydraulically trapped for thousands of years; ample time for the mineral CO_2 trapping reactions to take place. Thus CO_2 disposal in aquifers should be focused on the regional flow in the siliciclastic aquifers in sedimentary basins not on sedimentary traps. The paradigm of mineral trapping, identified in this report, increases tremendously the potential volumes of the subsurface available for CO_2 disposal.

6. More Detailed Studies of Aquifer Disposal is Warranted

This study has shown that the potential of subsurface CO_2 capture is very large for certain types of aquifers in the Alberta Basin. This study's extensive mineral reaction work is to be strongly promoted, but further work on long term reaction kinetics is needed to more fully define the increased CO_2 capture potential now indicated. Further geotechnical and geochemical work is essential to fully define the suitability of local aquifers and to select those most appropriate. As a first of a kind project, environmental control specifications, permitting, well design and system optimization will be extensive before an injection system can be put in place.

ACKNOWLEDGEMENTS

Ian Webster, IEA was a great help in identifying and helping with sources of potential funding for this project. Wayne Nesbitt, University of Western Ontario assisted with the clay-exchange calculations and the kinetic data. Daryl Wightman selected the core samples for us during a trip to ERCB. Finally we would like to thank our sponsors and their representatives on the management committee - Alberta Energy (D.E. Macdonald), Environment Canada (V.R. Marwaha), CANMET (F.M. Mourits), TransAlta (M.M. McDonald and D. Drysdale), and Edmonton Power (Doug Heaton).

1.0 INTRODUCTION

1.1 GENERAL

Currently, there is considerable interest in using geological structures (salt domes, brines, coal beds, oil and gas reservoirs, or aquifers), the deep ocean or enhanced oil recovery as sinks for disposal of waste gas, particularly CO_2. In the short term, enhanced recovery projects can utilize CO_2 if these projects are near the CO_2 source. However in the longer term, deep aquifers appear to offer the best promise for accepting large quantities of waste gases. Their global distribution and their large *disposal volume* are appealing for disposal of waste fluids or gases, particularly from point emission sources. Carbon dioxide is an ideal candidate for aquifer disposal because of its high density and high solubility in water at the relatively high pressures which may be imposed in aquifers.

This report summarizes experimental and desk studies relative to the potential for CO_2 disposal in certain aquifers in the Lake Wabamun area. The bulk of the effort was expended by the Alberta Research Council in examining the reactions between CO_2 and formation waters and minerals likely present in the specific aquifers.

This study has been financed by the Alberta Office of Coal Research and Technology (50%), Environment Canada (16.5%), Energy, Mines and Resources Canada (16.5%), TransAlta Utilities Corporation (8.5%) and Edmonton Power (8.5%). The latter two companies operate coal-based power plants with a total capacity nearing 4000 MW of net electrical output in the study area, with very major CO_2 capture and disposal potential.

The preliminary results of this study were reported at the Oxford University CO_2 disposal conference organized by the International Energy Agency's Greenhouse Gas Program. During the latter part of the study reported here, the study team carried out a preliminary study on aquifer disposal potential and its costs for the IEA. Each study has contributed to the other, and the facilities descriptions and costs of this study have been taken from the IEA study, but made specific to the Lake Wabamun area.

The study discussed here was planned as a first phase of a multi-phase program to develop an accurate appraisal of CO_2 disposal costs in the Lake Wabamun area. Further work will be required on many geological aspects in order to select and define a specific aquifer, and to define all facilities needed from power plant flue gas through to the aquifer.

1.2 STUDY TEAM

The study team was organized as follows:

●	T.J. McCann, SICL	Study Manager
●	R.B. Ramsay, SICL	SICL Facilities
●	W.D. Gunter, ARC	ARC Coordination, Geochemistry
●	E.H. Perkins, ARC	Geochemistry
●	S. Bachu, ARC	(Alberta Geological Survey) Geology
●	D. Law, ARC	Modelling
●	B. Wiwchar, ARC	Autoclave Experiments
●	Z. Zhou, ARC	Mineral Characterization

The team reported to the Owner's Group through a managing committee of Alberta Department of Energy's D.E. Macdonald, Environment Canada's V.R. Marwaha, CANMET's F.M. Mourits, TransAlta's M. McDonald and D. Drysdale, and Edmonton Power's D. Heaton.

2.0 SYSTEM OVERVIEW

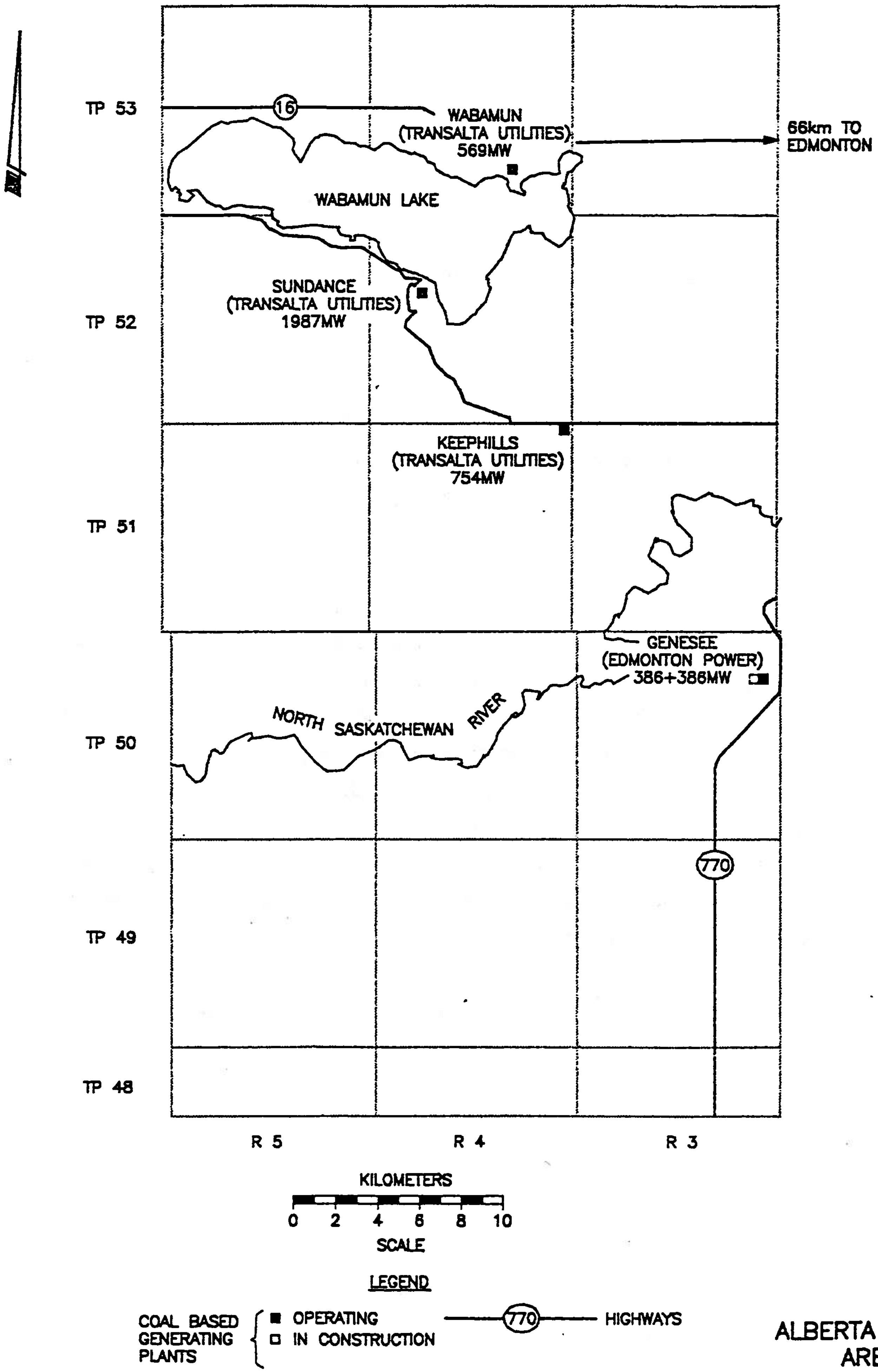
2.1 SETTING

The study area shown in Figure 2.1-1 was selected due to the presence of over two-thirds of Alberta's coal-based electricity generation. The area lies in the western Canadian sedimentary basin which contains many aquifers assumed to be suitable for CO_2 disposal.

While the study examined different types of aquifers, the facility data are based on use of the Lower Mannville aquifer formation as shown in Table 3.2 below. The Wabamun formation was also considered in reaction work as a representative of a carbonate aquifer as compared to a siliciclastic aquifer in the Lower Mannville.

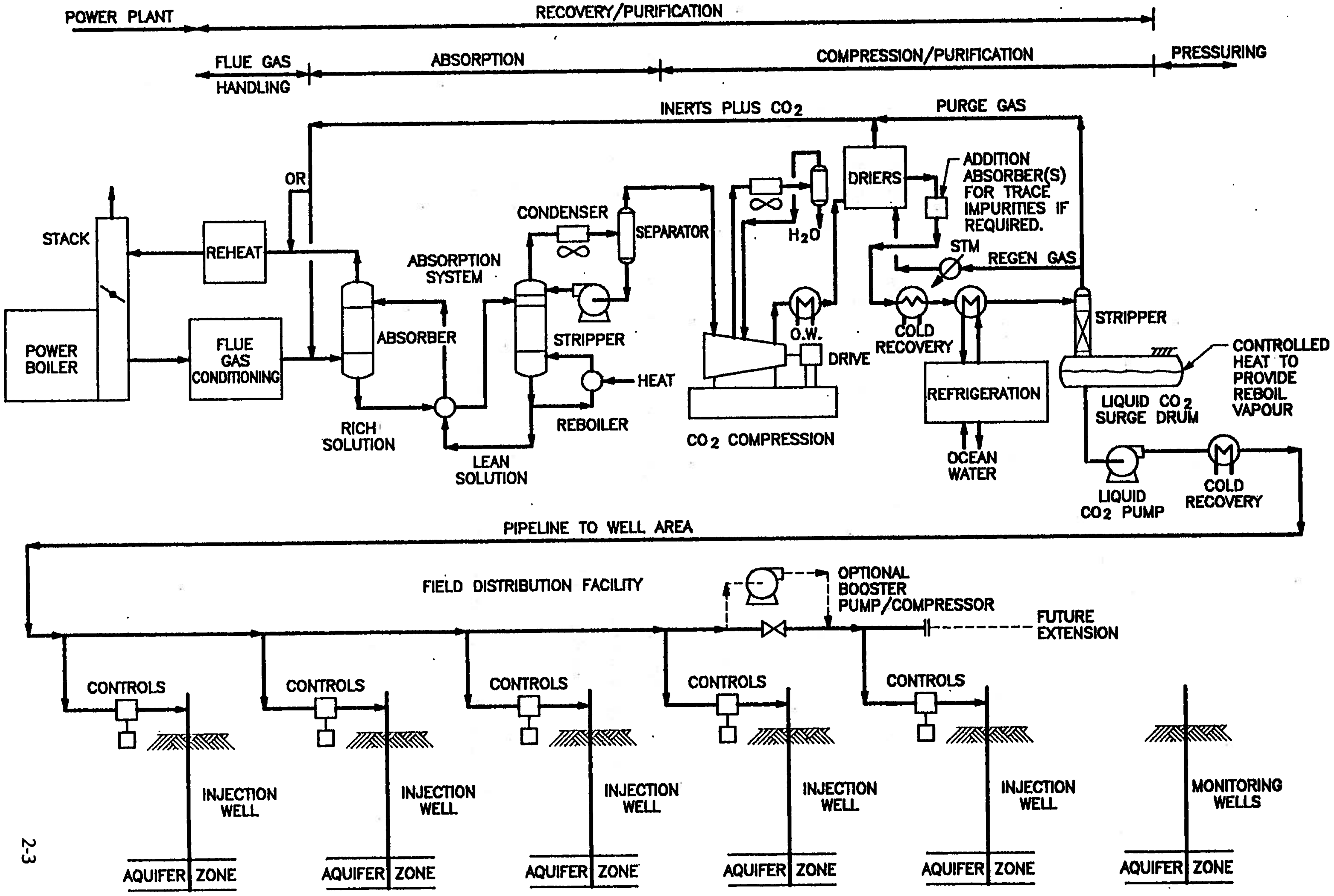
The capital costs of a field disposal system are minor compared to those of an overall CO_2 disposal scheme at a major power plant. Figure 2.1-2 provides a possible configuration assuming a chemical absorption approach to CO_2 capture. In the scheme shown, the impurities carried over from the CO_2 capture process are eliminated prior to CO_2 disposal. This minimizes corrosion potential and enhances the density and partial pressure of the CO_2 in the formation. The former is very important in determining the quantity of CO_2 in the supercritical vapour phase (still two-thirds of stored CO_2 10 years after injection ceases) and the latter is important in determining the amount of dissolved CO_2 (a slight decrease in solution CO_2 is evident in Figure 4.1-7 after CO_2 injection ceases and pressure declines as the pressure bulb continues to spread).

An injection rate of 1,000 tpd per well has been assumed at a station pressure of 21000 kPa.



ALBERTA STUDY AREA

FIGURE 2.1–1



OVERALL CO_2 DISPOSAL SCHEME
FIGURE 2.1–2

2.2 SOURCES

The sizes of the power plants in the study area are shown in Figure 2.1-1. The study area contains over two-thirds of the province's coal-based electricity generation with net capacity nearing 4000 MW. 500 MW of net electricity generation results in approximately 13,000 tonnes per day of CO_2 after correction for internal needs for CO_2 capture and production of a raw CO_2 gas stream near atmospheric pressure.

The addition of CO_2 compression and impurity removal itself requires in the order of 50 MW of electricity or equivalent, raising the CO_2 production to the order of 14,000 tpd (4.0 million tonnes a year) for 500 MW of sales to the provincial electrical grid. Thus, 15,000 tonnes per day appears to be a reasonable figure for preliminary system definition.

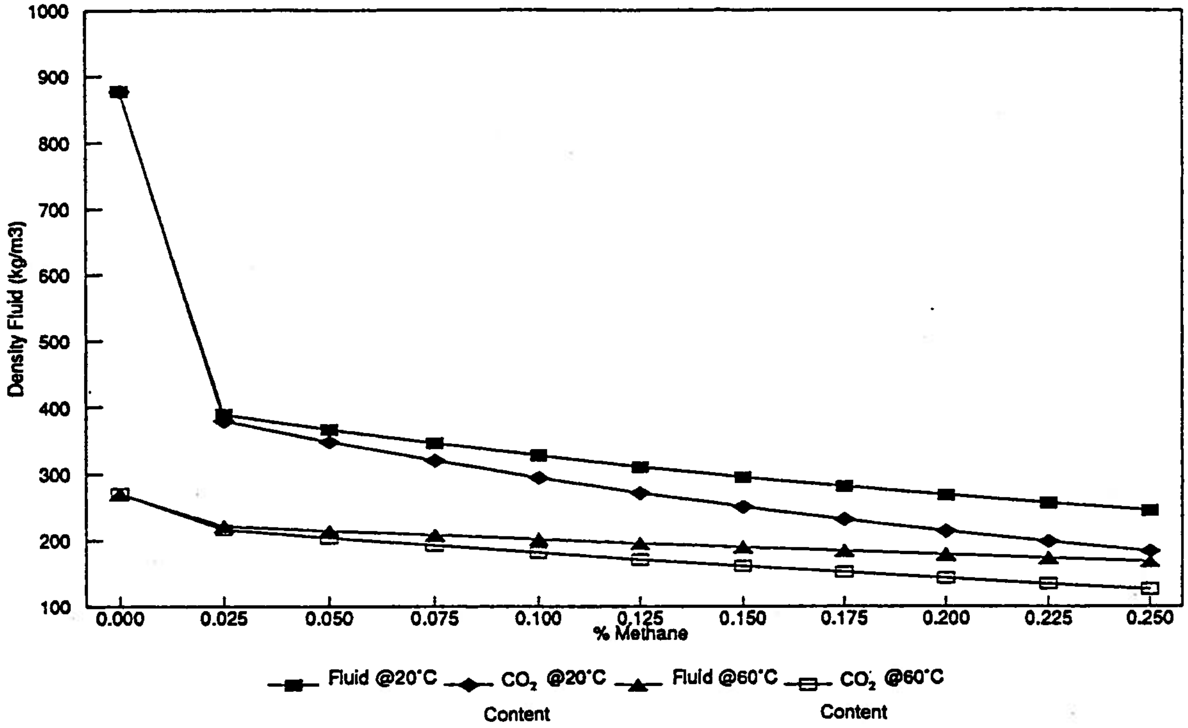
2.3 PURIFICATION AND PRESSURIZING

The above CO_2 rates allow for compression of the CO_2 to the 21000 kPa level required for local aquifer disposal. Figure 2.1-2 shows a possible system including an ability to reduce impurities to a very low level.

Figures 2.3-1 and 2.3-2 indicate the major impact on CO_2 density and, hence, on volumetric storage needs when traces of nitrogen and methane are present.

Figure 2.3-1
Impacts of Methane

Density Profile with Changing CH_4 Impurity
9660 kPa (1400 psig)



Density Profile with Changing CH_4 Impurity
19320 kPa (2800 psig)

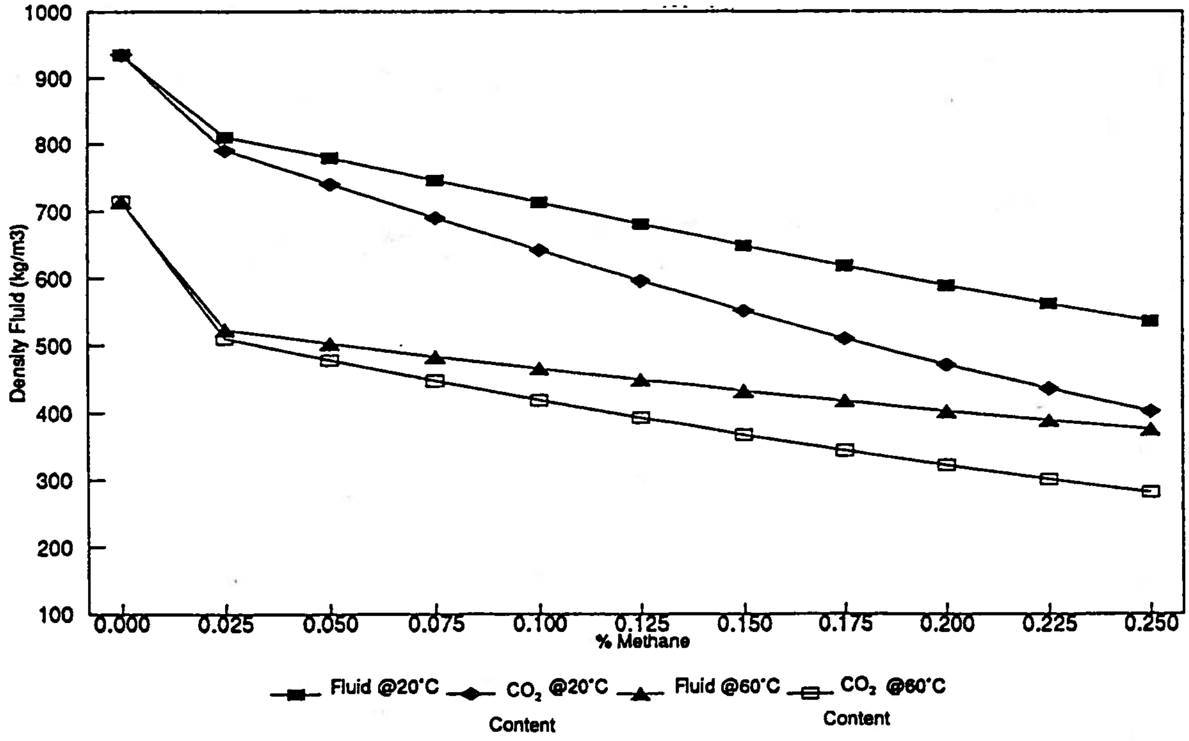
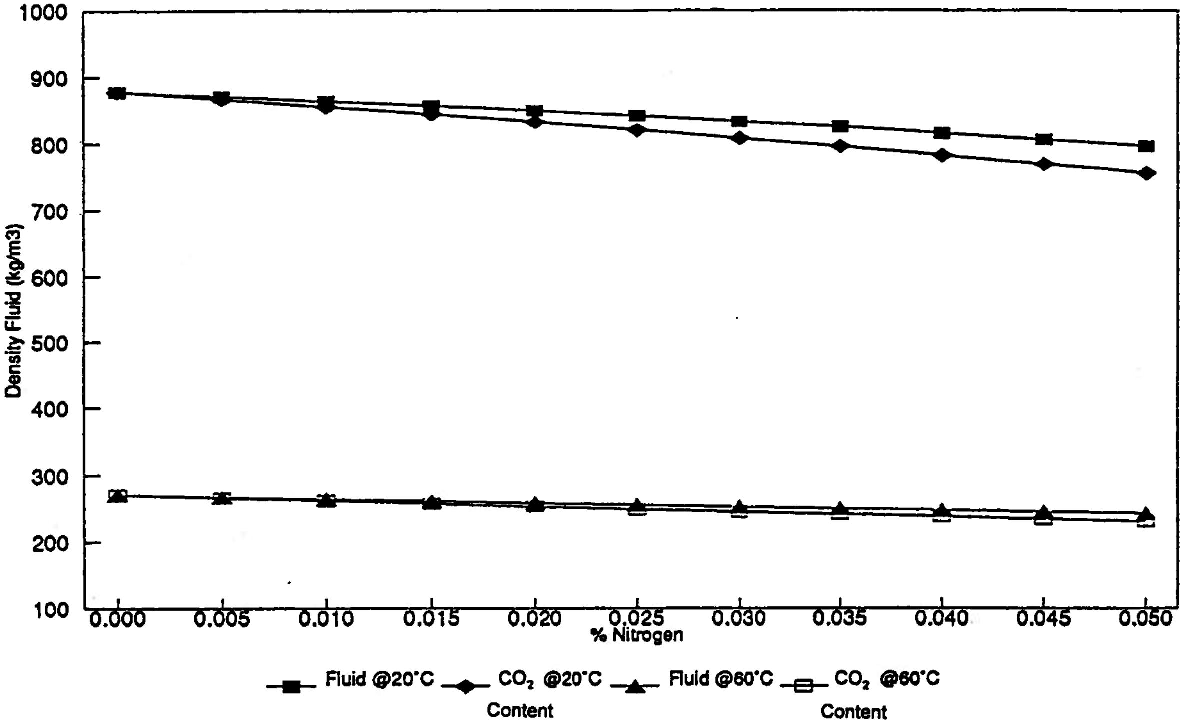
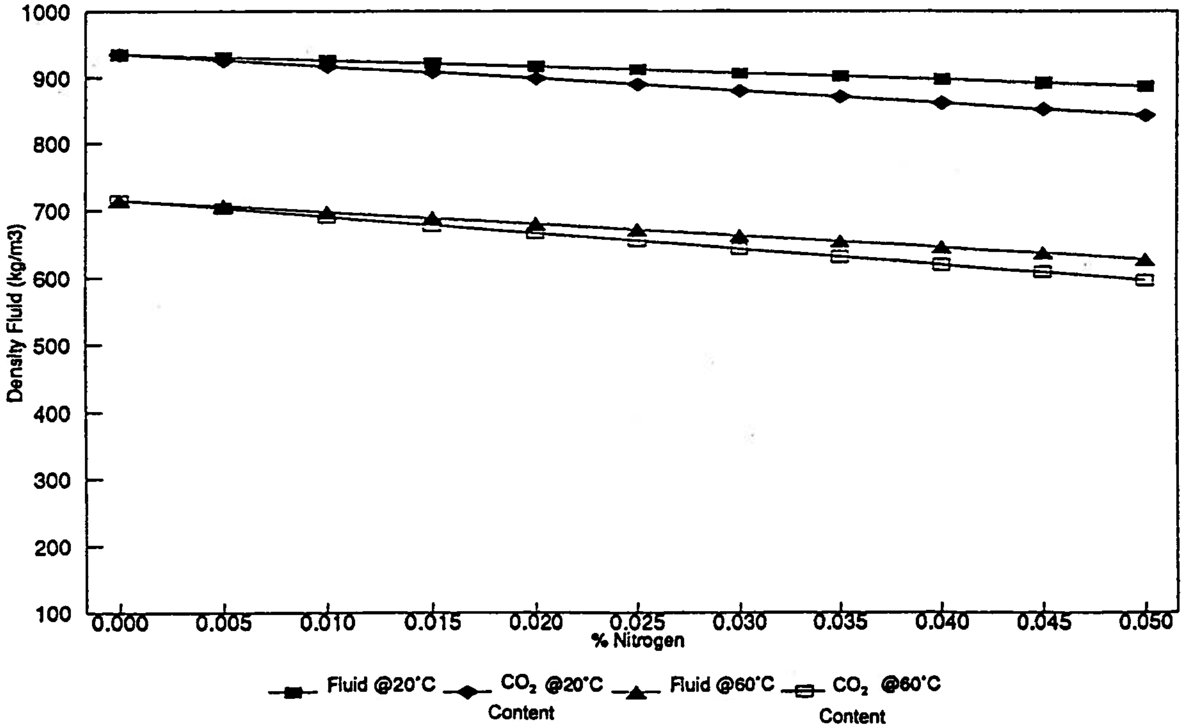


Figure 2.3-2
Impacts of Nitrogen

Density Profile with Changing N_2 Impurity
9660 kPa (1400 psig)



Density Profile with Changing N_2 Impurity
19320 kPa (2800 psig)



The impact is greatest in the well as the "liquid" head is greatly reduced with impurities - requiring much more compression at the station end. One major reason for past use of pure liquid CO_2 in oil and gas well fracturing was its high density - about that of water - minimizing pumping horsepower. There will also be increased pipeline costs when significant impurities are present as line sizes must be increased.

The capture system shown is typical of that used at many breweries and chemical plants, but is for illustration only; there are many optional routes. In such schemes, liquid CO_2 may best be transferred using reciprocating pumps (as proven in well fracturing).

The purification and pressurization system appears to be quite expensive, possibly in the order of $150 million in capital, broken into 4 or 5 trains. (Flue gas conditioning, CO_2 capture and plant derating costs must be added to that.) As noted above, pressurization is a very major energy user. The compression step is also a major energy user - in the order of 80 kWh/tonne.

2.4 FIELD FACILITIES

2.4.1 DISTRIBUTION PIPELINE

The pipeline itself will be designed to the equivalent of the U.S. ANSI B31.4 or Canadian CSA Z183 oil pipeline specifications, using all provisions for high vapour pressure liquid/supercritical fluid service (as with ethylene and ethane). These codes have different provisions for two areas of different population densities; here "Zone 1" (rural) of the CSA specification will be used.

A corrosion allowance would be added due to the possibility of moisture being present at some stage in the pipelines' life, tentatively 1.6 mm for the line and 3.2 for associated vessels. The depth of cover will vary with the specific code used and nature of the surrounding area, but a minimum burial of 1 metre is recommended in all areas to protect from farm and other machinery on the surface. Special attention and additional burial in casing will be needed at road and railway crossings to match codes and the risk of freeze bulbs from line breaks.

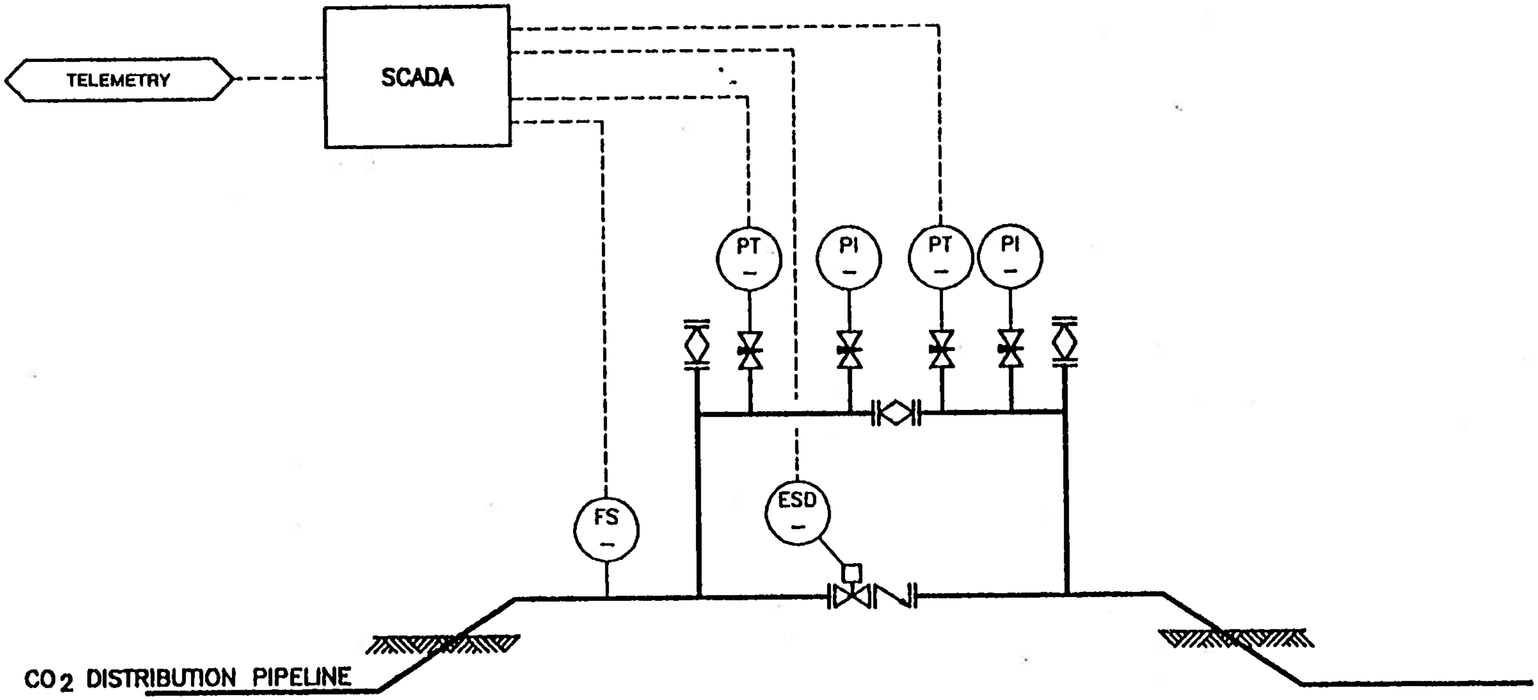
The pipeline will have automated block valves - as illustrated in Figure 2.4-1 - at a maximum spacing of 15 kilometres, on both sides of all river crossings, at major road and rail crossings, and at all transitions from one population zone to another. A SCADA system will regularly scan all valve positions and analyze pressures and flows throughout the system. A pipeline rupture will immediately block in the affected area and the system in general upstream of controls to individual wells.

The line will be sign posted as per normal pipeline practice, and all neighbours will be given educational sessions and literature, and will serve as unofficial monitors. All surface facilities, such as shutdown valves, will have locked, fenced enclosures. Spacing from houses, factories, etc., will follow the applicable codes. The use of high vapour pressure hydrocarbon standards will provide a margin of safety, but the heavy CO_2 vapour/solid from any line break will stay much closer to the ground than will high vapour hydrocarbons.

2.4.2 WELL SYSTEMS

2.4.2.1 SURFACE FACILITIES

The piping at the wells will be equipped as shown in Figure 2.4.2-1. A wellsite ESD valve will provide safety protection in case of a failure; this valve may be activated either locally or remotely through the SCADA system. A filter, with 5 micron elements, will ensure that particulate matter which could otherwise damage the well is removed from the CO_2 stream.

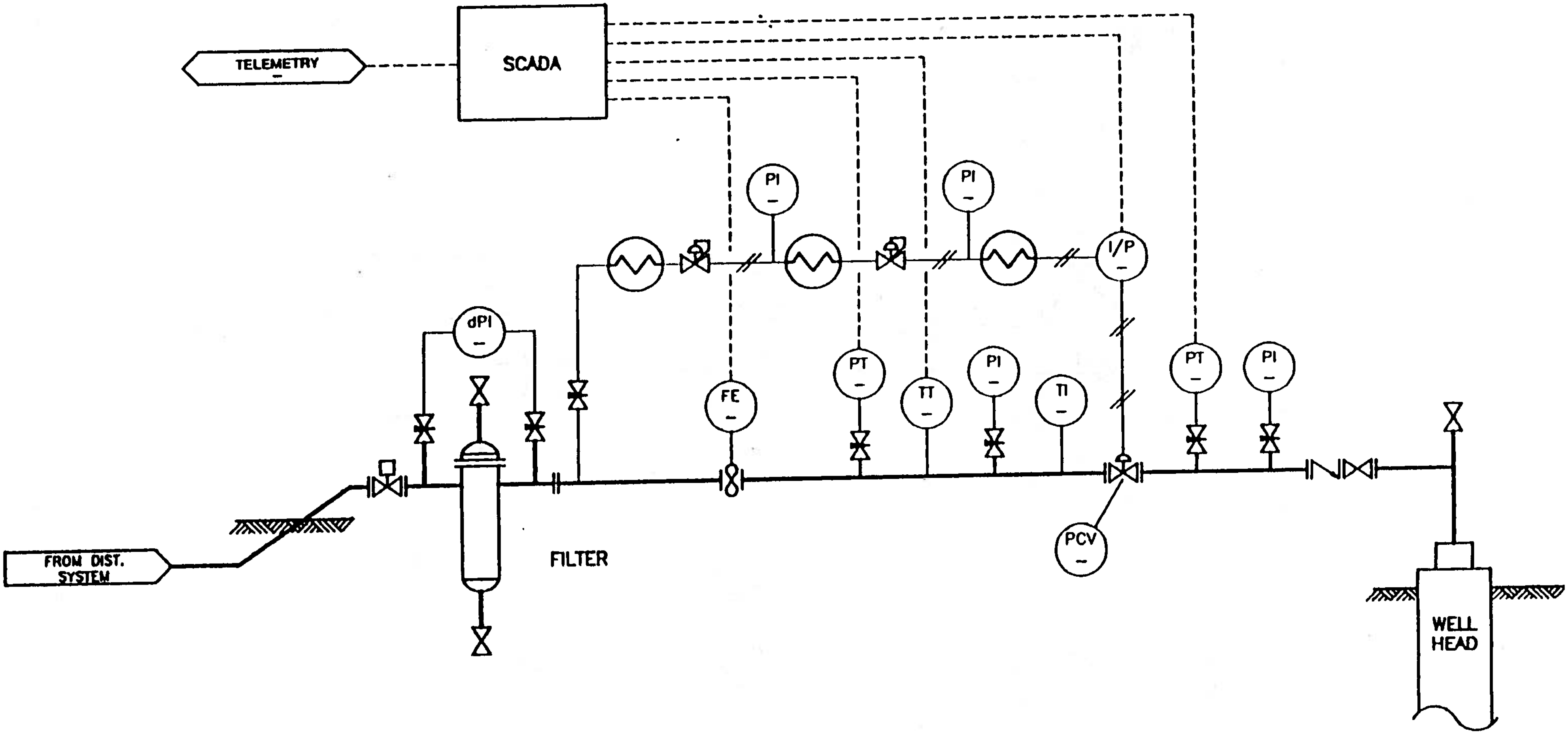


TYPICAL AUTOMATED
BLOCK VALVE STATION
FIGURE 2.4-1

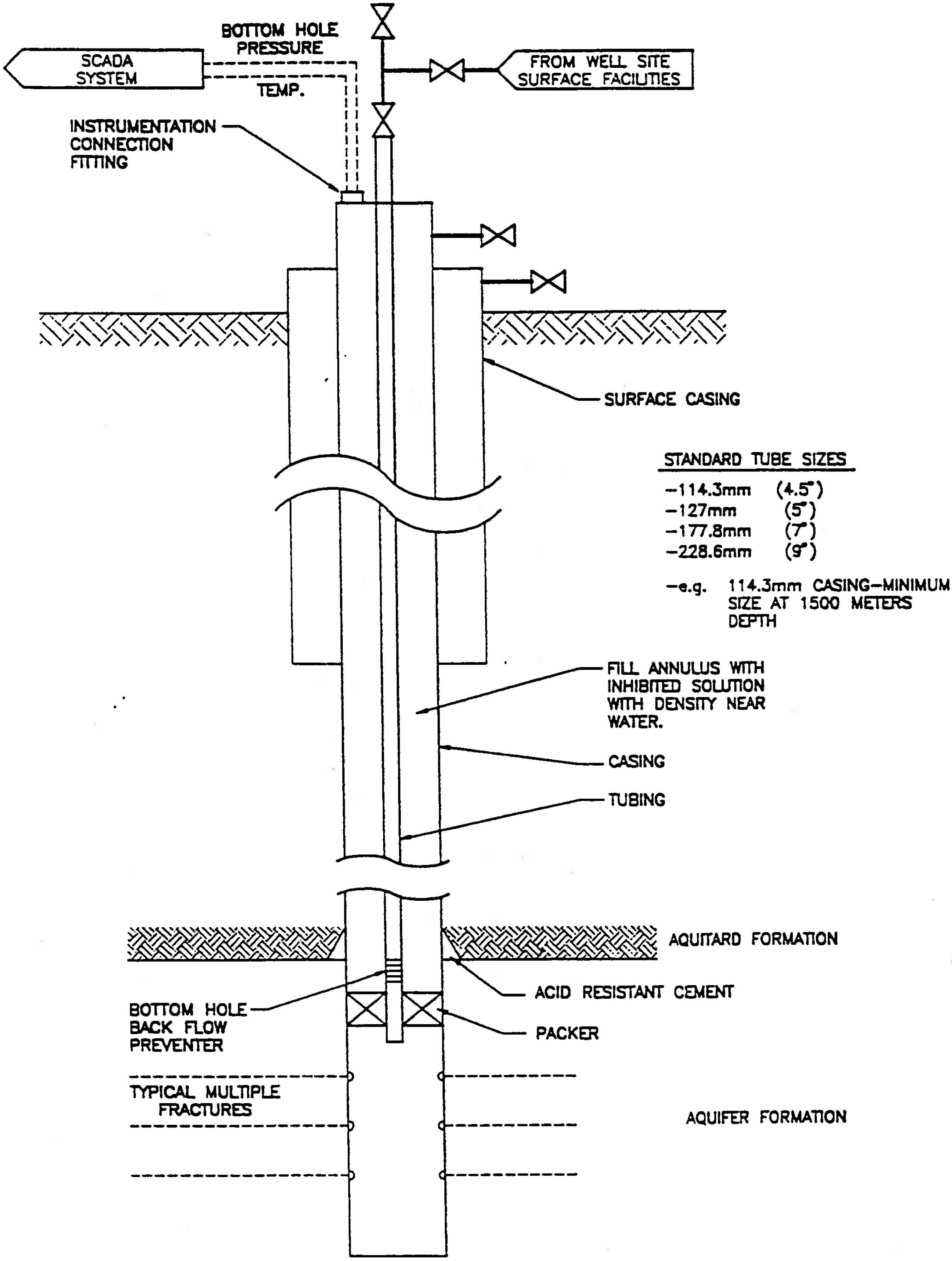
The meter measures the quantity of CO_2 being injected, and, via the SCADA system, provides the means to check for material balance for line break control. Pressure and temperature transmitters also form an integral part of the material balance instrumentation and monitor flowing conditions at the well. A control valve accepts signals via the SCADA system to apportion the total system flow to each well as required. This valve is also required for start-up of the injection, and to maintain a back-pressure for proper operation of the flow meter. A discharge check valve is provided for safety, to avoid back-flow production of previously injected CO_2 in an emergency situation. Local SCADA components and telemetry systems will be required, complete with a local uninterruptible power supply, possibly utilizing solar cells.

2.4.2.2 INJECTION WELLS

This system envisages wells similar to that shown in Figure 2.4.2-2. The downhole back pressure flow preventer is essential, protecting against well casing failure. The filling of the annulus with a dense fluid eliminates many stresses on the casing reducing potential corrosion.



SURFACE PIPING
AND CONTROLS
FIGURE 2.4.2-1



TYPICAL WELL
FIGURE 2.4.2-2

2.4.2.3 MONITORING WELLS

There will be two types of monitoring wells - those that will become future injectors and those that will continue as monitors. These wells will have bottom hole and above aquitard pressure sensors as well as a formation water sampling capability. The future injector category will be completed as per the regular injection wells, except that fracturing will be deferred. The monitoring only wells will tentatively have 60.3 mm tubing and 114 mm casing. All wells will be designed to good oil and gas field practice, recognizing the low pH regime in the aquifer, particularly near the well.

2.5 SYSTEM COSTS

2.5.1 ESTIMATES

2.5.1.1 INTRODUCTION

This section provides guidelines for the preparation of cost estimates for the installation and operation of facilities for the transportation, distribution and injection of CO_2 from a source location to injection wells. This section covers measurement, control, pumping, medium and high pressure pipelines, wellsite facilities and high pressure pipelines, and their operations. Costs are in 1993 Canadian dollars and are based on typical Canadian conditions. No attempt was made to select a specific location or route, nor to identify particular costs which may be associated with a specific location and not to another location. CO_2 capture and purification costs, and well drilling, completion and workover costs are not included.

The costs have been derived from Stanley's extensive data base of costs for similar projects completed, underway, or under study. However, the data have been adjusted to apply specifically to CO_2 injection project use, and are not suitable for other purposes.

The cost data have been assembled to provide a relationship between cost and other parameters, such as pumping power, pipeline size, or throughput capacity. Before attempting to estimate costs, these basic parameters must be determined. Therefore, in the next step, a layout of the proposed system must be prepared, and each of the components identified. The size or capacity of each component is determined from the appropriate sizing charts or other engineering methods. The unit cost for each component is then determined, using the appropriate curve, and this cost multiplied by the quantity included in the project.

The cost curves, in keeping with the nature of this report, are generic only. For any given situation, the costs may be higher or lower due to factors not considered herein. Further, the owner of the facility has many options in selecting plant design, to sacrifice higher operating costs to achieve lower investment costs, and certain design innovations may result in higher or lower costs. Finally, costs may vary to accommodate planned future increases or decreases in throughput volumes.

2.5.1.2 FIELD FACILITY INVESTMENT COSTS

The investment costs are intended to be total installed costs for the facility, including land acquisition, engineering, inspection, and owner's administration and overhead costs. They do not include costs for feasibility studies or other "pre-project" expenses. However, commissioning and start-up costs are included. Operator training is included in Operations Costs and is therefore not included here.

METERING AND SCADA

The investment costs for an inlet metering and control station, including system Supervisory Control and Data Acquisition (SCADA), are shown on Figure 2.5.1.2-1. This is assumed to be a shop-fabricated, skid-mounted assembly on a concrete slab base. A separate prefabricated building, also mounted on a concrete slab, houses control and telemetry equipment, and provides a small office. The telemetry communications system is assumed to be via VHF radio, and the base station, with its antenna tower, is included in these costs. It has been assumed that the CO_2 product is dry and pure when received, and no costs for purification are included. The station is assumed to be located on the source plant site property, and no land costs or utility connection costs are included. No provision is made for warehousing of spare parts, nor for a system operations centre with shop and office facilities.

HIGH PRESSURE TRANSPORTATION PIPELINE

The appropriate pipeline size must first be determined based on length and capacity required, from Figure 2.5.1.2-2. The investment costs for a high pressure pipeline to transport CO_2 from the source location to the disposal area are shown on Figure 2.5.1.2-3. These curves cover the typical costs for pipelining in undeveloped low cost (flat pasture land) and in medium cost (acreages or forested) areas. The following assumptions were made in developing these curves:

- Pipeline maximum operating pressure 10,000 kPa (use of ANSI 600 rated flanges).
- Corrosion allowance 1.6 mm (1/16 inch).
- Rural location with undulating hills but no steep gullies or other barriers.
- Clay, silt or till overburden with minimal gravel and no rock.
- Depth of cover 1 m on all lines.
- River, highway, railroad crossings are extra to the base cost.
- No restricted right-of-way width or route access.
- Local availability of labour, equipment and materials for construction.

Figure 2.5.1.2-1
Meter Station and SCADA Costs

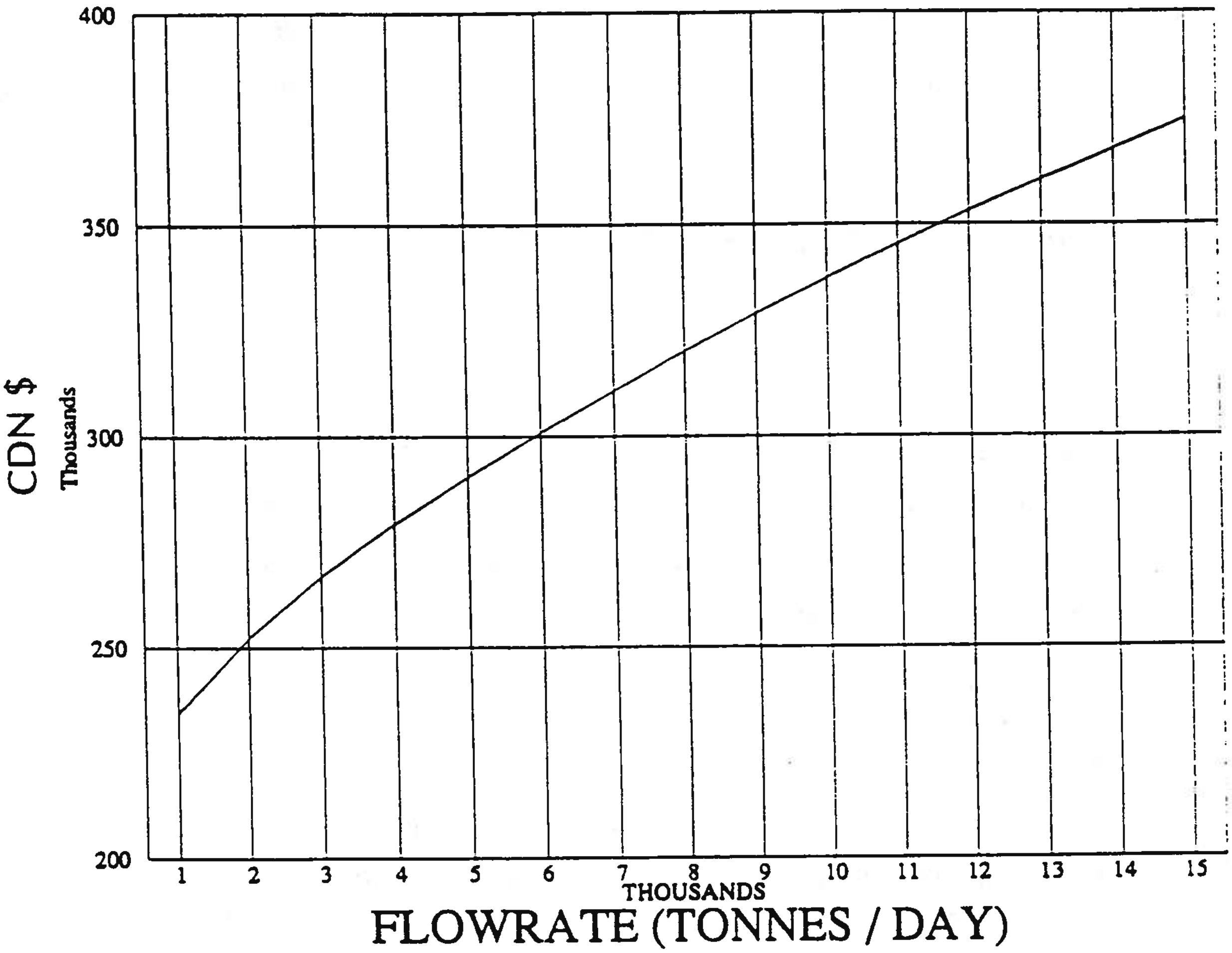


Figure 2.5.1.2-2
Line Sizing

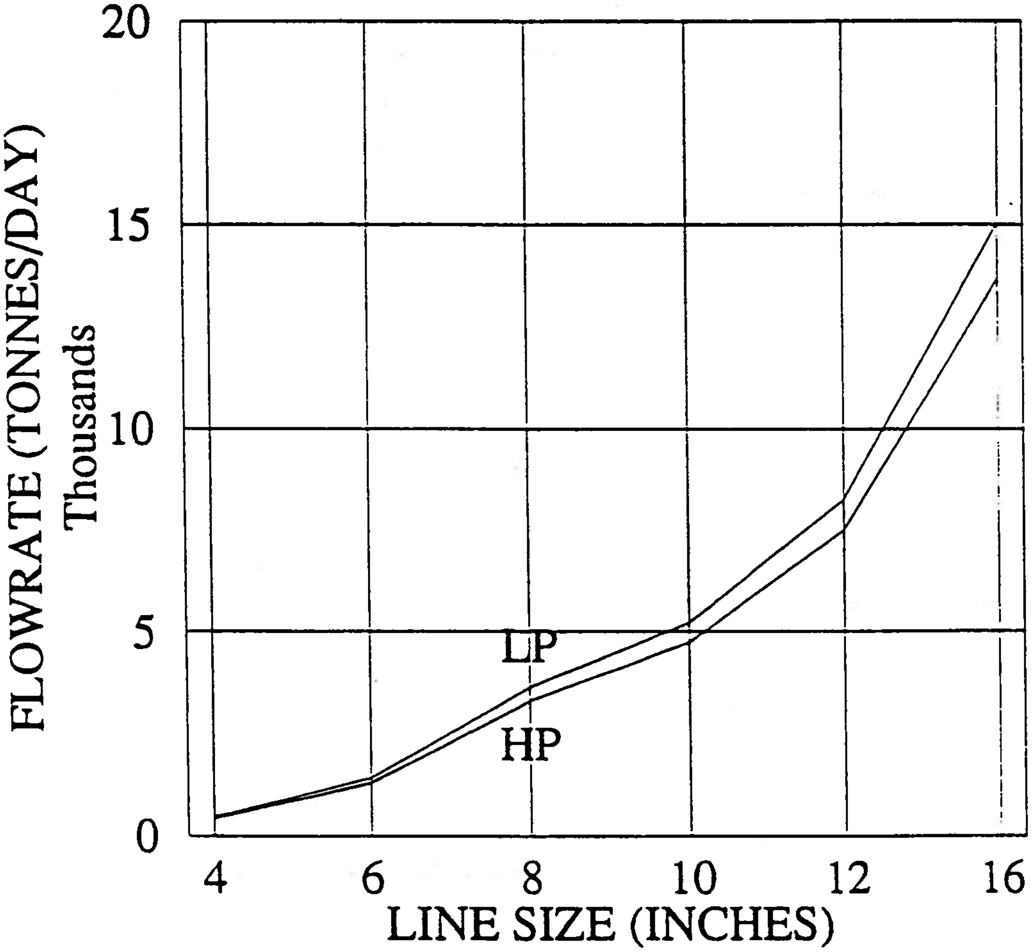
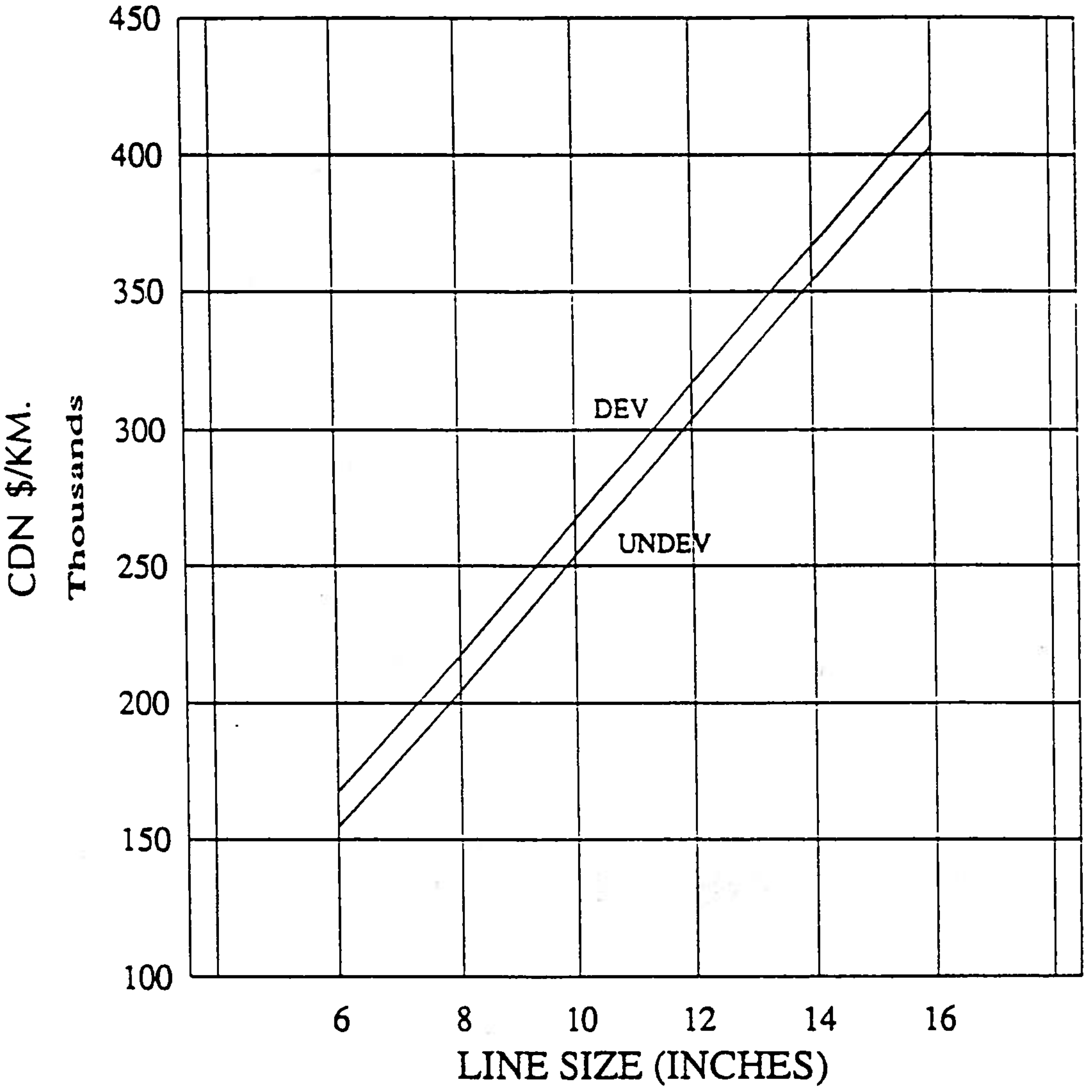


Figure 2.5.1.2-3
CO_2 Pipeline Costs
High Pressure Pipeline
$ Range Developed Versus Undeveloped Land



- Restoration typical of pasture or farm land.
- Survey, inspection, 100% radiography, cathodic protection, engineering and overhead costs are included. An allowance for an environmental impact assessment and extraordinary permitting costs must be added.
- The base costs include a simple riser at each end, but do not include intermediate block valve assemblies or other appurtenances.

MISCELLANEOUS PIPELINE COSTS

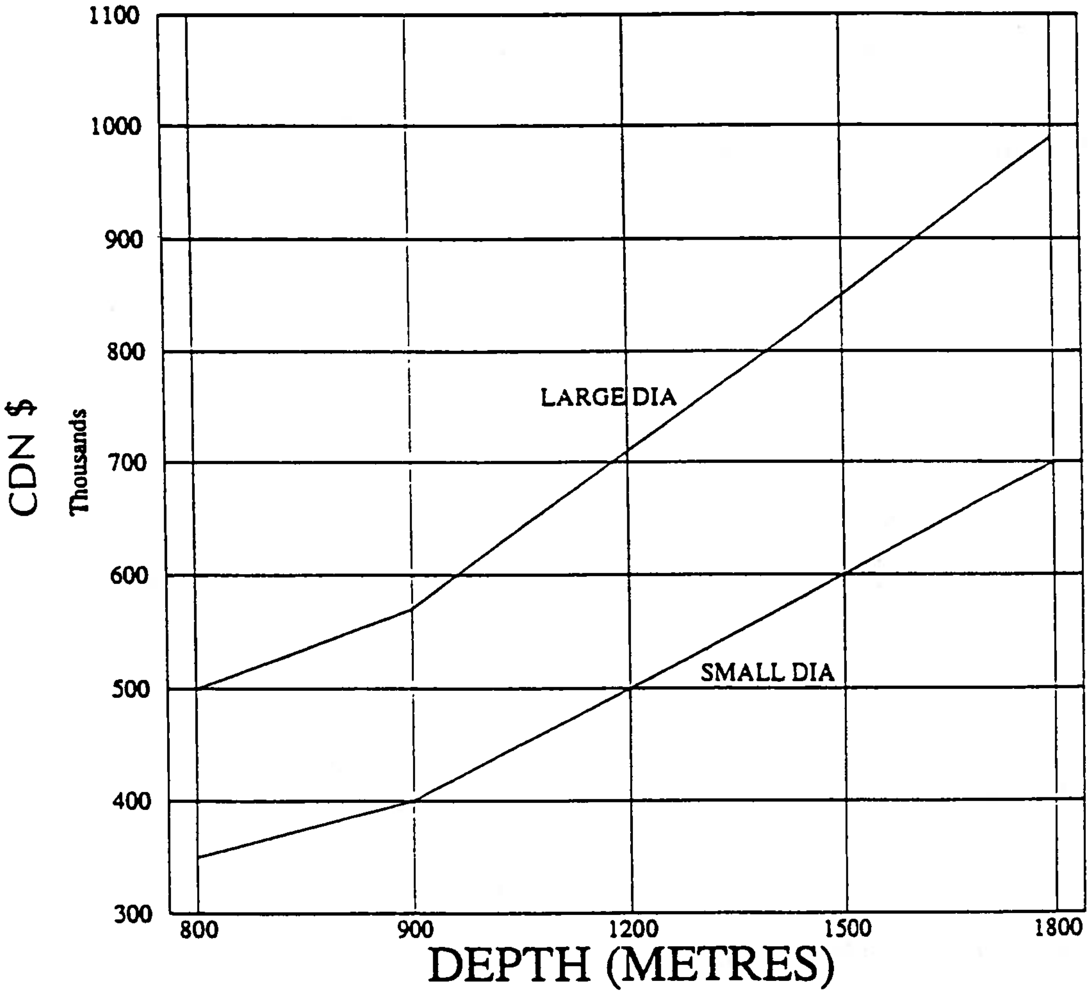
Costs have been obtained from Stanley's data base for specific items, to be added for total pipeline costs. These items have not been included in the premises of this report, as they are somewhat unusual in the pipelines under consideration.; but are presented here for information purposes only:

Rock Excavation (Blasting or Air Tool Removal)	Add $180.00/m
River Crossing Directionally Drilled	Add $1,100.00/m
Railroad or Highway Crossing (Bored)	Add $200.00/m
Automatic (SCADA) Block Valve Assembly	Add $10,000.00 for each assembly

WELLSITE FACILITY COSTS

The investment costs for wellsite facilities and individual wells, as a function of well injection capacity, are shown on Figure 2.5.1.2-4. These cover filter assembly, control equipment, SCADA and telemetry equipment, and associated piping and valves.

Figure 2.5.1.2-4
Well and Wellhead Costs



The figure includes costs for drilling and completing injection wells. These costs may also apply to observation wells if required (with the smallest size to be used). It is assumed that drilling rigs would be available within a reasonable proximity to the well site to minimize mobilization costs. Also, it is assumed that well site access is good, and that environmental and drilling/completion regulations similar to that in Alberta environmental and drilling would apply.

DECOMMISSIONING

All wells but those selected for ongoing monitoring must be properly abandoned at the end of the injection period.

Such costs will be significant at that time, but not on a net present value basis. The scrap value of pipelines is unlikely to be enough to cover the cost of reclaiming land, even in remote areas, and such lines will probably be left in place with concrete or other fill to maintain structural integrity.

While on a present value basis, decommissioning costs are minuscule, future decommissioning must be considered in all designs and operating procedures.

2.5.1.3 FIELD OPERATING COSTS

Supervising labour, maintenance and various insurances will cost approximately 10 percent of the facility capital cost. But such costs are very site specific.

2.5.2 SYSTEM DEVELOPMENT

From the above discussion, it is obvious that much preliminary and detailed effort is needed even before an aquifer disposal system becomes a project. The following is a brief review of key factors in pre-project costs:

2.5.2.1 GEOLOGICAL AND GEOPHYSICAL DEVELOPMENT

These are also discussed later in Section 12. There will be a wide range of costs but a range from $1,500,000 appears likely for exploratory/confirmation drilling (which will also provide the requisite water and matrix samples), and the related engineering, geological, geophysical and geochemical services.

2.5.2.2 EXTERNAL RELATIONS

A very approximate estimate of $500,000 is projected for this area, covering environmental studies and impact assessments, regulatory agency negotiations and citizen acceptance programs.

2.5.2.3 LAND ACQUISITION

Land costs will vary more than any other variable between different settings. For this report, land and related acquisition fees have been valued at $3,000 per hectare. Up to 5 hectares are required per kilometre of pipeline and 3 hectares for each well.

2.5.2.4 PROJECT COORDINATION

The development of a pressurizing, distribution and well system will take project management time and expenses not included elsewhere in the cost estimates. Such costs are expected to be in the order of $1,000,000 for a Wabamun area project.

2.5.3 COST SUMMARY

Table 2.5.3-1
Wabamun Area Disposal System Capital Costs
for CO_2 from a 500 MW Power Plant
in Millions of 1993 Canadian Dollars

Facility	
• Meter Station	0.2
• Pipeline 30 km @ $300,000	9.0
• Wells 15 @ $800,000 (Injection)	12.0
• Wells 16 @ $550,00 (Monitoring)	8.8
Sub Total	30.0
Overheads	
• Geotechnical	1.0
• Permitting et al	0.5
• Land Acquisition	0.7
• Project Coordination	1.0
Sub Total	3.2
Overall Total	**33.2**

The accuracy of the overall costs are expected to be in the order ±35 percent.

Operating costs for the disposal pipeline/well system will be in the order of $2,000,000 a year. Note that the above does not include cost originating inside the power station/capture/compression facility envelope.

2.6 ENVIRONMENTAL FACTORS

This study did not investigate environmental factors in any detail, but the following comments came out of this study and the IEA study:

a) In this area the study team believes that injected CO_2 can be contained in the formation.

b) Monitoring wells will be needed to ensure no undue fingering of CO_2-rich materials occurs until pressures have declined to near background levels (in the long future).

c) The use of high vapour pressure liquid pipeline codes and practises should be used.

d) SO_2 must be kept to very low levels, as CO_2 leaks will remain close to the surface. In the case of large leaks, dry ice crystals will increase the density of the leaking CO_2 cloud even more than normal.

e) Valley routing should be avoided and any river crossings have automated valves on either side to minimize CO_2 release.

f) Only minor biota damage is foreseen from leaks.

3.0 REGIONAL GEOLOGY

3.1 GENERAL

The Alberta Basin comprises a wedge of sedimentary rocks that thickens westward from a zero edge at the Canadian Shield to more than 6 km at the foreland thrustfold belt. The basin can be divided into two distinct tectono-sedimentary realms: the passive margin and the foreland basin. The Cambrian to Jurassic passive-margin phase of basin development consisted of dominantly carbonate sedimentation, with periods of clastic and evaporite deposition. Starting in Jurassic time, the western margin of the basin changed to a site of active compressional tectonism. The Jurassic to Tertiary foreland basin is dominantly comprised of clastic rocks (sandstone and shales) which were shed from the developing orogenic belt to the west. Adjacent to the Canadian Shield, the regional dip of Palaeozoic strata is approximately 4 m/km, while that of the overlying Mesozoic strata is only 1.4 m/km. Approaching the foreland thrustfold belt, the regional dip of the Phanerozoic strata increases to 10 m/km. A more detailed overview of the regional geology in the Alberta Basin is given by Porter et al. (1982).

The above simplified and general description of basin geology is important for understanding the hydrostratigraphy, mineralogy and properties of any aquifer selected for the subsurface disposal of CO_2 in Alberta. Carbonate aquifers are found at greater depths than sandstone aquifers. Any given regional aquifer is found at shallower depths in the east than in the west. Because of pre-Cretaceous to recent erosion, some aquifers present in the west are truncated or absent in the east. The salinity of formation waters in the Palaeozoic aquifers is generally high, while in the Cretaceous aquifers is generally low (Hitchon et al., 1989, 1990; Bachu and Underschultz, 1993). Aquifer properties like porosity and permeability tend to vary with location and depth (Bachu and Underschultz, 1992). Geothermal gradients, hence formation temperature, vary on a regional scale from southwest to northeast (Bachu and Burwash, 1991). Thus, there is no single "characteristic

Table 3.1
Stratigraphy, Lithology and Hydrostratigraphy of Selected Sedimentary Strata in the Area Defined as Tp. 49-52, R3-5, W5Mer, in Alberta

	STRATIGRAPHY	LITHOLOGY	HYDROSTRATIGRAPHY
CRETACEOUS	Edmonton Gp.	Sandstone/Shale	aquifer
	Belly River Fm.	Sandstone	aquifer
	Lea Park Fm.	Shale	aquitard
	Colorado Gp.	Shale	aquitard
	Upper Mannville	Sandstone	aquifer
	Clearwater	Shale	aquitard
	Lower Mannville	Sandstone	aquifer
CARB.	Rundle Gp.	Dolomitic limestone	aquifer
	Banff Fm.	Limestone/Shale	aquifer/aquitard
	Exshaw Fm.	Shale	aquitard
DEVONIAN	Wabamun Gp.	Limestone	aquifer
	Winterburn Gp.	Dolomite	aquifer
	Ireton Fm.	Shale	aquitard

aquifer" in the Alberta Basin, or no aquifer can be characterized by single values of salinity, pressure, porosity, permeability, and the like.

3.2 AQUIFER PETROPHYSICS

For the purpose of this study (proof of concept for the subsurface disposal of CO_2) there is need for some realistic aquifer characteristics in order to perform geochemical and fluid flow numerical modelling of CO_2 injection. Keeping in mind that, for economical and environmental reasons, the captured CO_2 should be disposed of close to the generating power plant, a region west of Edmonton was chosen for aquifer identification and characterization. The area, defined by Tp. 49-52, R 3-5, W5 Mer, is in the immediate vicinity of the Sundance and Genesee power plants. Based on the general stratigraphy of the sedimentary strata in the area, regional siliciclastic and carbonate aquifers were identified in the area at depths between 1400 and 2000 m. These aquifers are deep enough to be part of regional flow systems isolated from the surface by extensive regional aquitards, yet relatively shallow (as much as possible) in order to minimize drilling costs. Table 3.1 presents the stratigraphy, main lithology and hydrostratigraphy of the stratigraphic succession of interest. The aquifers selected for proofing the CO_2 disposal concept are the carbonate Wabamun (Devonian) and the sandstone Lower Mannville (Cretaceous). Major regional confining aquitards in the area are the Colorado, Clearwater, Lower Banff and Ireton shales.

The determination of characteristic values for the geochemical, hydrodynamic and geothermal parameters of interest for the two selected aquifers is based on the extensive data bases, data base management system and data processing software implemented at the Alberta Geological Survey. An electronic data base for all the wells in Alberta is maintained and updated regularly based on the Energy Resources Conservation Board (ERCB) releases. A search through this data base identified 754 wells in the area of interest. Based on stratigraphic information from these wells, a representative depth and thickness was determined for the Wabamun and Lower Mannville aquifers (Table 3.2).

An electronic data base of cored intervals and core analyses in Alberta wells is maintained at the Alberta Geological Survey based on ERCB public information. The data base was searched first to identify cored intervals in the two aquifers. This information (Appendix 11.3.1) was subsequently used to collect core samples for mineralogical analysis, to be used in geochemical modelling of CO_2 disposal.

A typical core-plug analysis contains information about, among other things, the maximum permeability in the horizontal plane, k_m, the permeability k_{90} in the horizontal plane normal to the direction of maximum permeability, the permeability in the vertical direction, k_v, and porosity ϕ. The core-plug analyses for Wabamun and Lower Mannville rocks in the area of interest were extracted from the data base and culled for erroneous values. The porosity and permeability data obtained from core analyses represent volume-averaged values corresponding to the measurement (plug) scale. In order to characterize the two aquifers, a sequential scaling-up process must be used (Cushman, 1984). The plug-scale porosity and permeability data were scaled-up first to the well scale and then the well-scale values were scaled-up to the formation (aquifer) scale (Bachu and Underschultz, 1992). Characteristic porosity and permeability values for the two aquifers are presented in Table 3.2. These values are of the same order of magnitude as the characteristic values for the same or similar units elsewhere in the basin (Bachu and Underschultz, 1992, 1993). Because these representative porosity and permeability values were generated from plug-scale measurements, they are characteristic of the movement of fluids through the pore space only. They do not characterize the movement of fluids through large-scale features such as vugs, caverns or fractures, which are beyond the resolution of plug-scale measurements. Thus, the large-scale permeability and porosity in the carbonate Wabamun aquifer may be larger. Nevertheless, studies based on drillstem

Table 3.2
Characteristic Properties of Selected Deep Aquifers in the Area Defined as Tp. 49-52, R3-5, W5Mer, in Alberta

Aquifer	Wabamun	Lower Mannville
Depth (m)	1,800	1,450
Thickness (m)	170	55
Salinity (mg/l)	160,000	75,000
Pressure (kPa)	15,000	11,300
Max. Permeability k_m (mD)	2.2	1.3
Standard Dev. of k_m (mD)	n.a.	4.0
Horizontal anisotropy	n.a.	0.65
Vertical anisotropy	0.82	0.30
Porosity ϕ (%)	8	12
Standard dev. of ϕ	n.a.	3.5

tests elsewhere in the basin (Hitchon et al., 1989; Bachu and Underschultz, 1992) suggest that the order of magnitude is correct.

Other parameters of interest for aquifer characterization and hydrodynamic simulation of CO_2 disposal are formation pressure, temperature and thermal conductivity. The formation pressure for the two aquifers of interest in the area was obtained from the electronic data base of drillstem tests implemented at the Alberta Geological Survey. Representative values are given in Table 3.2. Characteristic temperature values can be calculated based on aquifer depth, an annual average ground temperature of 6°C and a geothermal gradient of 23°C/km in the area (Bachu and Burwash, 1993). Finally, the thermal conductivity of aquifer rocks can be calculated based on rock thermal conductivity values (4.17 W/m°C for sandstone, 3.46 W/m°C for limestone and 3.3 W/m°C for dolomite) corrected for temperature and porosity effects (Bachu, 1993).

3.3 AQUIFER FORMATION WATER CHEMISTRY

An electronic data base of approximately 150,000 analyses of formation waters in British Columbia, Alberta and Saskatchewan is maintained at the Alberta Geological Survey. Previous studies in the Basin (Hitchon, 1989, 1991; Hitchon et al., 1987, 1989, 1990) have shown that as few as one-fifth of standard formation water analyses in any particular area may be suitable for consideration after culling by appropriate automatic and manual procedures. Typically, analyses can be contaminated, mixed with other samples, or be incomplete. The automatic cull takes into account the presence and values of OH, CO_3, Ca, Mg, Cl, SO_4, HCO_3, acceptable ranges of pH and density, and mixing of formation waters from several intervals. The formation water analyses for the Wabamun and Lower Mannville aquifers in the area of interest were culled mechanically and screened manually resulting in 135 representative analyses (Appendix 11.3.2). Representative TDS (Total Dissolved Solids) values are shown in Table 3.2.

The TDS contents of the formation waters in the potential disposal horizons are usually high and increase significantly with depth. They range from 70,000 mg/L in the Cretaceous formations to well over 170,000 mg/L in the Devonian formations. Several formations in this region have anomalous formation water compositions when compared to the rest; for example, the Glauconitic formation with a TDS in the range of 4200 mg/L.

The formation water compositions vary significantly with depth and laterally, but the dominant cation is almost always sodium. The maximum sodium concentration is in excess of 50,000 mg/L, the maximum potassium concentration exceeds 30,000 mg/L and the maximum calcium concentration exceeds 10,000 mg/L. Typical calcium concentration ranges are in the hundred mg/L range. Except in the dilute fluids, the dominant anion is chloride which can reach levels in excess of 100,000 mg/L in the brines. Sulphate can reach levels of 5,000 mg/L which appears to correlate to high potassium levels. Total alkalinity levels are typically in the 600 mg/L range, with highs over 1,100 mg/L and lows less than 100 mg/L. For most of the waters, the milli-equivalent range for alkalinity is less than that of calcium. The pHs for these waters are typically in the high 7 to low 8 range; however, extreme values down to 6.1 and up to 9.1 are reported. The analyses were used subsequently in the geochemical modelling of CO_2 disposal.

3.4 AQUIFER FORMATION MINERALOGY

Ten core samples were selected from the cored intervals of siliciclastic and limestone aquifers listed in Appendix 11.3.1 and were collected from the ERCB core facility in Calgary as potential material for the validation experiments. Only seven core samples were available and their formations are listed in Table 3.3. Thin sections and bulk XRD were made from each of the samples. XRD tracings for the seven samples are included in Appendix 11.3.3. The mineralogy is listed in Table 3.4. The modal mineral concentrations for all 7 samples are estimated from XRD peak intensity.

Table 3.3
Aquifer Formation
Samples from ERCB

CO2 INJECTION STUDY--SAMPLES

SAMPLE #1	4-14-51-4W5 DEPTH 6410.5 FT(1953.8M) POROUS CARBONATE
SAMPLE#2	02/16-18-49-4W5 DEPTH 1775.95M POROUS CARBONATE (SANDY IN PT.)
	NO CORE @ 1725M IN 02/16-18-49-4W5
SAMPLE#3	02/16-18-49-4W5 DEPTH 1777.28M CALCAREOUS SAND(UNDERLIES CARB.-SAMPLE#2)
SAMPLE#4	6-18-50-3W5 DEPTH 1555.65M BIOTURBATED SANDSTONE
SAMPLE#5	1-6-50-3W5 DEPTH 1610.05M CALCAREOUS SANDSTONE 1607-1609.75M = SHALE WELL LOG OR CORE POSSIBLE OFF DEPTH
SAMPLE#6	10-2-50-3W5 DEPTH 1566.25 CALCAREOUS SAND
	NO CORE @1548M 10-2-50-3W5 CORE STARTS @ 1564M
SAMPLE#7	16-9-51-4W5 DEPTH 1580.0M CALCAREOUS SAND
8-31-49-5W5	NO SAMPLE TAKEN -ZONE =TIGHT CARBONATE(NO POROSITY)- 3M BELOW=30CM CHERT CONGLOMERATE ALSO TIGHT
	NO CORE @ 1940M-WABAMUN(8-31-49-5W5)

Sample #1 is a siliciclastic dolostone; dolomite dominates in the sample with about 5% of quartz and 1% K-feldspar. Samples #2, #5, and #7 are siliciclastic limestone. Calcite is the dominant mineral in these three samples, with some quartz and fluorapatite. Sample #3 has complex lithology, varying from highly phosphatic, siliciclastic limestone to highly calcareous, siliciclastic phosphate rock. Major minerals in Sample #3 are quartz, calcite, and fluorapatite. Sample #4 is a calcite cemented, well sorted quartz sandstone. Clay minerals in the sample cannot be detected by XRD method but can be seen under optical microscope. Sample #6 is a calcareous sublitharenite, containing mainly quartz and calcite with minor amounts of siderite and dolomite.

Sample #4 was chosen for the validation experiments because it represented most closely the formation mineralogy expected in a good siliciclastic aquifer.

Table 3.4
Mineral Composition

Sample	Calcite	Dolomite	Quartz	Fluora-patite	Others
#1	--	94	5	--	K-feldspar: 1
#2	90	--	5	5	--
#3	35(33)	--	45(25)	20(39)	--
#4	5(16)	--	95(70)	--	Clays: (3)
#5	92	--	5	3	--
#6	30(40)	2(2)	65(47)	--	Siderite: 5(5)
#7	95	--	2	3	--

Note: Mineral concentrations are shown in terms of relative peak intensities. Numbers in brackets are the modal fraction estimated from optical microscopy.

4.0 NUMERICAL SIMULATION OF AQUIFER INJECTABILITY

4.1 DESCRIPTION OF NUMERICAL SIMULATOR

The numerical model used in this study was the STARS 4.0.2 developed by the Computer Modelling Group (CMG) in Calgary, Alberta. STARS 4.0.2 is a four-phase, multi-component thermal STeam and Additive Reservoir Simulator. Some of the novel features of STARS, including fully implicit wells and thermal aquifer model, were used in this study (STARS, 1990).

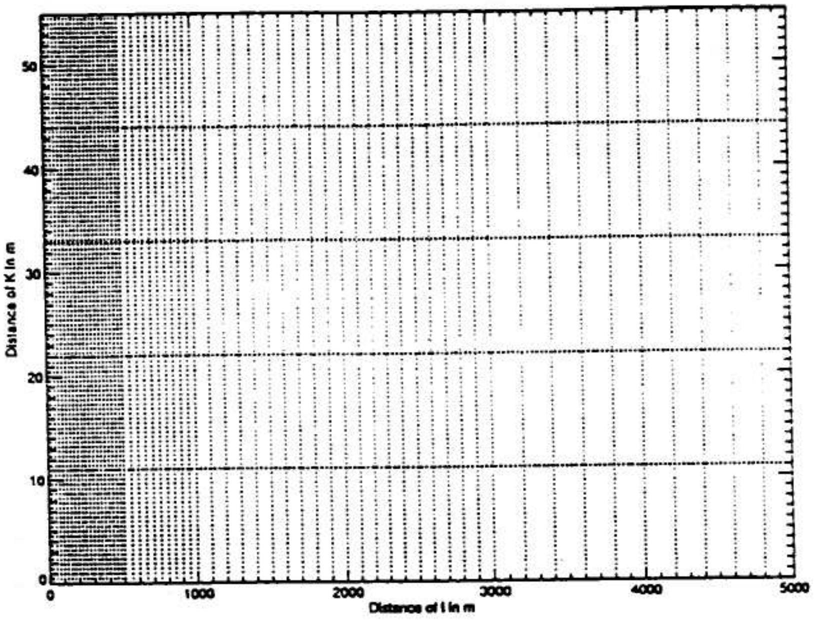
The numerical simulation was a 2-D cylindrical pattern simulation based on a Lower Mannville siliciclastic aquifer in the Wabamun Lake area in Alberta. The numerical simulation was isothermal at the average temperature of the aquifer.

A 2-D cylindrical grid pattern with 330 ($I = 66, J = 1, K = 5$) grid blocks was used to subdivide a region of the aquifer into discrete segments, with a radius of 5 km (Figure 4.1a) around a vertical injector. At the outflow boundary, a semi-analytical thermal aquifer model (Appendix 11.4.1) was used to calculate the water flow from this region to an infinite aquifer. There was a finer grid resolution near the injector which was located at the axis of symmetry ($I = 1$). The grid block sizes in the radial direction (I-direction) were varied from 1 m near the injector to 200 m near the outflow boundary. On the other hand, the grid block sizes in the angular (J-direction) and the axial direction (K-direction) were uniform with dimensions of 360° and 11 m, respectively.

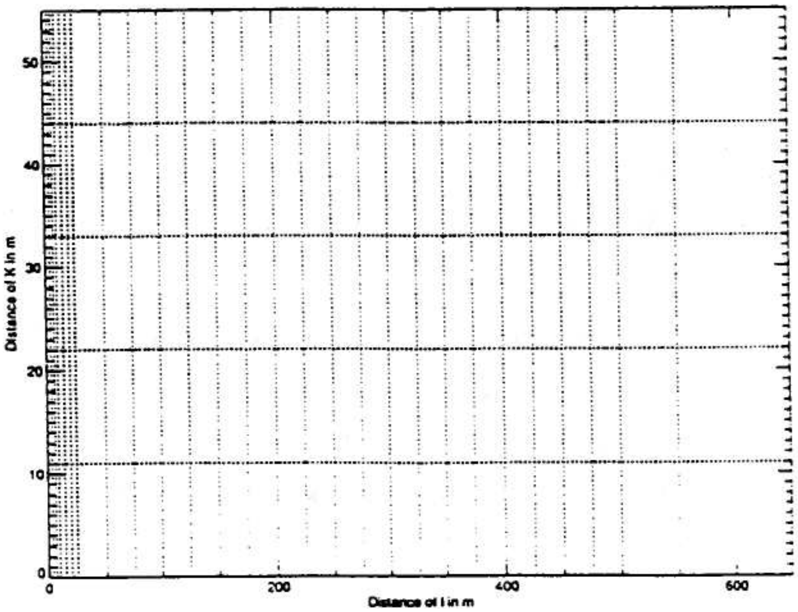
In some numerical runs, a 2-D cylindrical grid pattern with 140 ($I = 28, J = 1, K = 5$) gridblocks was used to blow up a region of aquifer with a radius of 0.65 km (Figure 4.1b) around the injector. All numerical runs were performed on a Sun Workstation, SPARC station 2. Typical runs with 330 and 140 gridblocks took approximately 6 and 2.5 CPU hours, respectively.

Figure 4.1
Grid Pattern

Gridblock sizes not in scale



(a) 66 × 1 × 5 (Location of Aquifer Outflow Boundary = 5 km)



(b) 28 × 1 × 5 (Location of Aquifer Outflow Boundary = 0.65 km)

4.2 PHYSICAL PROPERTIES OF THE AQUIFER

The objective of this numerical study is to investigate the potential for subsurface disposal of CO_2 in Alberta. The aquifer selected is a Lower Mannville siliciclastic aquifer in the Wabamun Lake area, Alberta.

The aquifer which is 1450 m underground and 55 m thick was assumed to be homogeneous in this study. The absolute permeabilities in the horizontal and the vertical directions were 1.3 and 0.39 mD, respectively, and the porosity is 12%. The pressure at the top of the aquifer is 11.3 MPa. The average temperature of the aquifer is 40°C, which was estimated based on a ground surface average temperature of 6°C and a geothermal gradient in the area of 23°C/km.

A density of 2643 kg/m^3 and a compressibility of 4.7×10^{-7}/kPa were used for the sandstone in the numerical simulation. The fracture pressure at the top of the formation was 32.8 MPa. It was estimated based on a gradient of 22.61 kPa/m (i.e. 1 psi/ft) that related the minimum principal stress to the weight of the overburden (Tremblay, 1993).

The thermal conductivity of the sandstone could be estimated using the following correlation:

$$k_{th}(T) = k_{th}(20) \; X \; 293 \; / \; (T + 273) \qquad (1)$$

where $k_{th}(20)$ is the thermal conductivity at 20°C and T is temperature in °C. For sandstone, $k_{th}(20)$ = 4.17 W/m-°C and $k_{th}(40)$ could be estimated as 3.9 W/m-°C.

The carbon dioxide in the aquifer was in supercritical conditions and was treated as a single phase fluid in the numerical simulation. The densities of CO_2 at 40°C varied from 638 kg/m^3 at 10 MPa to 907.7 kg/m^3 at 30 MPa (Clark, 1966). The viscosity of CO_2 at

40°C and 20 MPa was 0.077 cp (McHugh and Krukonis, 1986). The effect of pressure over a range of 10 to 30 MPa on the viscosity of CO_2 was neglected in this study.

The CO_2 was allowed to dissolve in water in the numerical simulation due to the high solubility of CO_2 in water. However, the solubility of water in CO_2 was relatively small and was neglected in the numerical simulation. The K values for CO_2 in water at 40°C could be estimated from SOLMINEQ.88 using the following correlation (Kharaka et al., 1988):

$$\log K = -2.419 + 0.9838 \log P \tag{2}$$

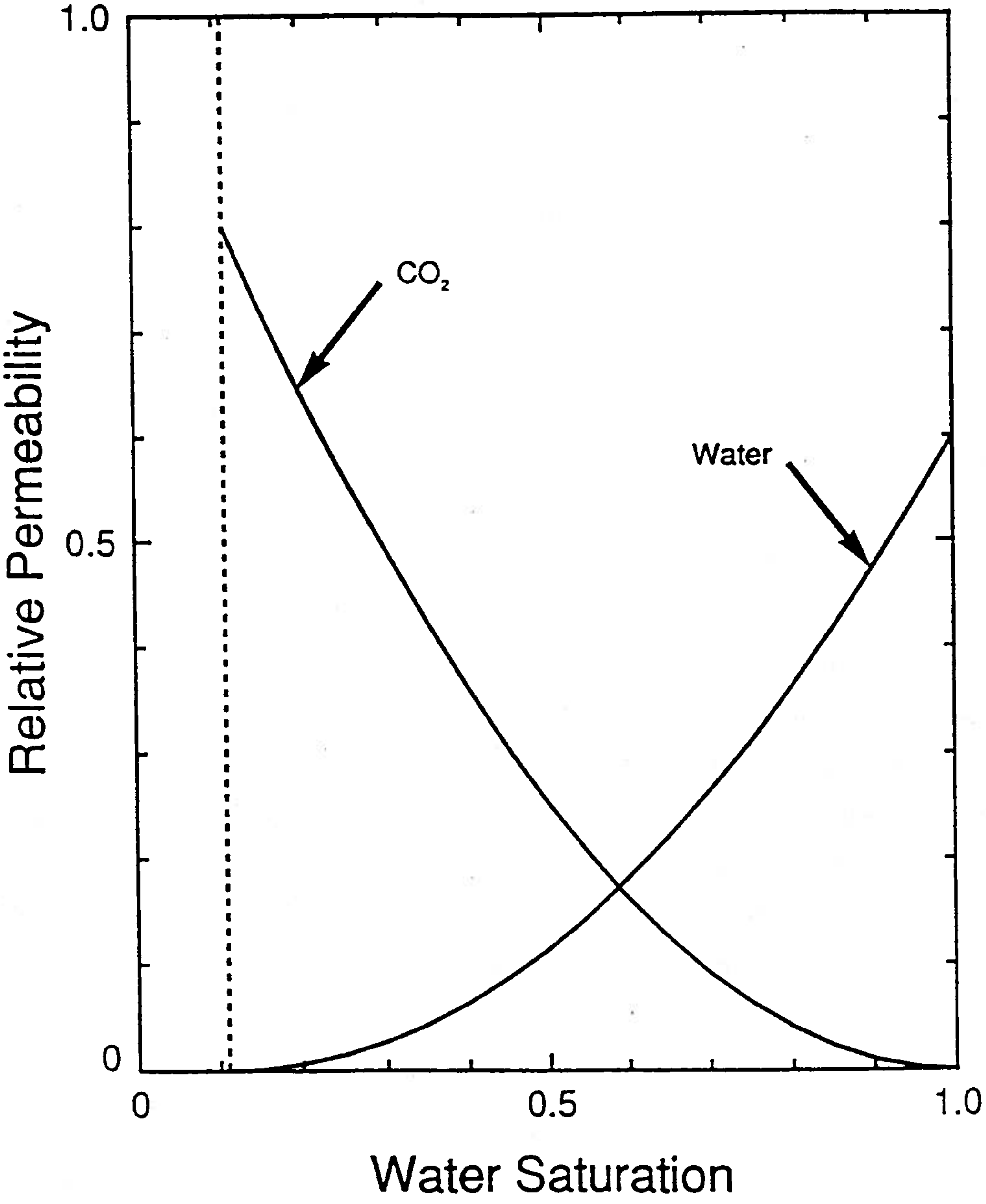
where K is the mole fraction of CO_2 dissolved in water and P is the pressure in MPa. From Equation (2), the K values for CO_2 in water varied from 0.0367 at 10 MPa to 0.1082 at 30 MPa. It is noted that the density of the CO_2 in water phase was set to the same density of the water.

The relative permeability curves for the water-CO_2 system are given in Figure 4.2. The supercritical CO_2 was treated as a single fluid which had behaviour between a gas and a liquid. Hence, a zero residual saturation was chosen for the CO_2 relative permeability curve. It is noted that the relative permeability curves were not measured but typical curves for the water-oil system in Alberta oil reservoirs.

The capillary pressure effect was neglected in the numerical simulation. Firstly, the capillary pressures of the water-CO_2 system in the aquifer were unknowns. Secondly, capillary pressure effect may not be significant as the pressure changes (in the order of 1-10 MPa) during the CO_2 injection were one or two order of magnitude higher than the estimated capillary pressures.

Figure 4.2
Relative Permeability Curves for Water-CO_2 System

End Point for CO_2 Relative Permeability Curve = 0.8
End Point for Water Relative Permeability Curve = 0.6
Residual CO_2 Saturation = 0
Irreducible Water Saturation = 0.11



4.3 INJECTION STRATEGIES

In the numerical simulation, 100% CO_2 at 40°C was injected at a constant injection pressure of 29.5 MPa (i.e. 90% of the fracture pressure of 32.8 MPa at the top of the aquifer). The vertical injector penetrated the entire thickness of the aquifer. In all numerical runs, the injector was either completed at an interval of 11 m at the bottom of the aquifer ($I=1, K=5$) or at an interval of 55 m covering the entire thickness of the aquifer ($I=1, K=1 \rightarrow 5$). The injector radius was either 3 inch or 4 inch.

A list of the numerical runs is given in Table 4.1. Numerical runs CO2_6-9 which all simulated a 30-year CO_2 injection period, were conducted to investigate the effects of location of aquifer outflow boundary, injector size and injector completion. Numerical run H2O_4 which simulated a 30-year water injection period, was conducted to investigate the effect of injected fluid. Numerical run CO2_12, which simulated a 30-year CO_2 injection period plus a 10-year period after the shut-in of the injector in a hypothetical aquifer with absolute permeabilities 10 times those of the Wabamun Lake aquifer, was conducted to investigate the effect of permeability.

4.4 INJECTIVITY OPTIMIZATION

Numerical predictions of cumulative CO_2 injection, CO_2 injection rate and CO_2 saturation contours as a function of time are given in Figures 4.3-4.10 for numerical runs CO2_6-9. In general, CO_2 propagated less than 600 m away from the injector after an injection period of 30 years. Approximately 26 to 29 wt % of the injected CO_2 dissolved into water. There was evidence of CO_2 override to the top of the aquifer when the injector was completed near the bottom of the aquifer (runs CO2_6 and CO2_7). The override of CO_2 was more significant when the completion of the injector covered the entire thickness of the aquifer (runs CO2_8 and CO2_9).

The effect of aquifer outflow boundary location could be studied by comparing the results from runs CO2_6 and CO2_7. The location of the aquifer outflow boundary had very little effect on the amount of CO_2 injected as shown in Figure 4.11. A comparison of pressure distribution after 30 years at a depth of 45.9 m from the top of the aquifer (i.e. the centre of gridblocks at K=5) as shown in Figure 4.12 also indicated that by moving the outflow boundary from 5 km to 0.65 km, there was very little effect on the numerical predictions. By moving the outflow boundary from 5 km to 0.65 km, the number of gridblocks could be reduced from 330 to 140 and the CPU time of the numerical run could be reduced by more than half. The numerical results indicated that choosing a 3 inch radius injector with a completion of 11 m near the bottom of the aquifer, an average of approximately 100 t/day of CO_2 could be injected into the Wabamun Lake area aquifer without fracturing. At this CO_2 injection rate, the average water rate due to the CO_2 injection at 5 km from the injector was less than 0.11 cm/year as shown in Figure 4.13. This indicated that the CO_2 disposal operation had an insignificant effect on the natural flow of the aquifer (approximately 1 cm/year) far away from the injector.

The effect of injection radius and completion could be studied by comparing the results from runs CO2_7-9. It is noted that the injection rate is directly proportional to the completion interval of the injector and is inversely proportional to ln (1/injector radius). As shown in Figure 4.14, by increasing the completion interval from 11 m to 55 m, the average CO_2 injection rate increased from 100 t/day to approximately 180 t/day. On the other hand, by increasing the injector radius from 3 inch to 4 inch, there was very little effect on the amount of CO_2 injected. Slightly more CO_2 could be injected when a 4 inch radius injector was chosen. A comparison of pressure distribution after 30 years at a depth of 45.9 m from the top of the aquifer as shown in Figure 4.15 indicated that aquifer was pressurized faster when a larger completion interval was chosen due to the higher injection rate.

Table 4.1
Numerical Runs

All runs simulated a 30-year CO_2 injection period.

Grid Pattern: 66 X 1 X 5 (Location of Aquifer Outflow Boundary = 5 km)

Run No.:	Injected Fluid:	Injector Radius:	Injector Completion:
CO2_6	CO_2	3"	11 m
CO2_12*	CO_2	3"	55 m
H2O_4	H_2O	3"	11 m

* For Run CO2_12, the absolute permeability in the horizontal and the vertical directions were 13 and 3.9 mD, respectively. Run CO2_12 simulated a total of 40 years that included a 10-year period after the shutin of the injector.

Grid Pattern: 28 X 1 X 5 (Location of Aquifer Outflow Boundary = 0.65 km)

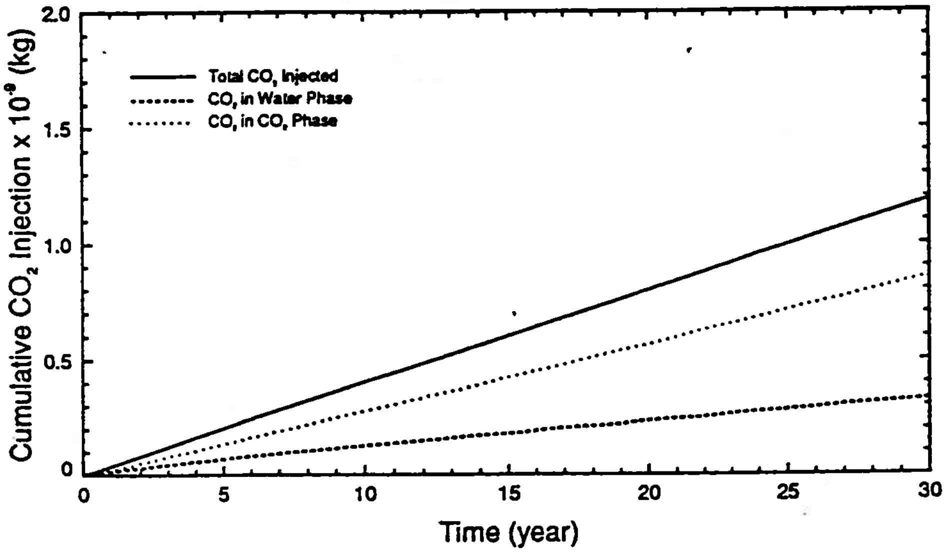
Run No.:	Injected Fluid:	Injector Radius:	Injector Completion:
CO2_7	CO2	3"	11 m
CO2_8	CO2	3"	55 m
CO2_9	CO2	4"	55 m

Figure 4.3
CO_2 Injection for Numerical Run CO2_6

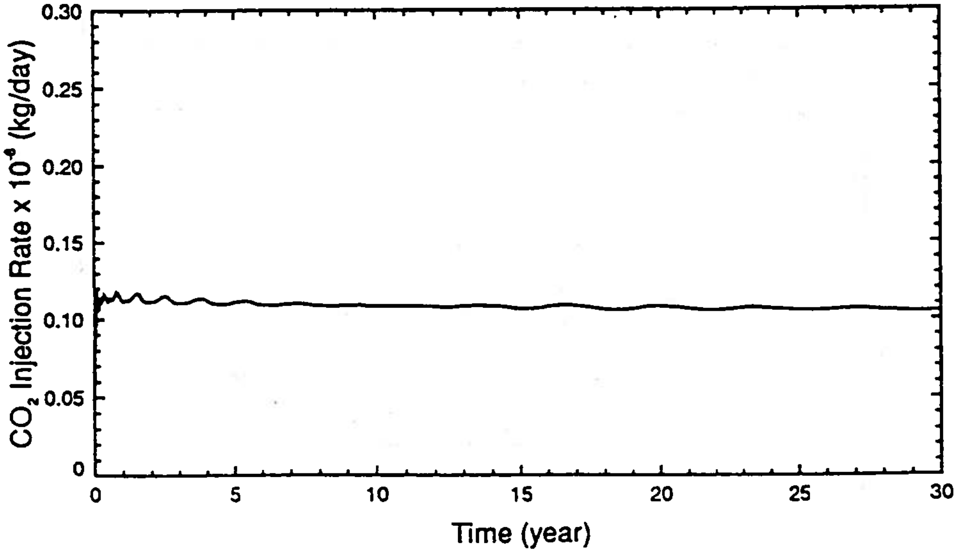
Location of Aquifer Outflow Boundary = 5 km

Injector Radius = 3" Injector Completion = 11 m (Bottom)

(a) Cumulative CO_2 Injection



(b) CO_2 Injection Rate



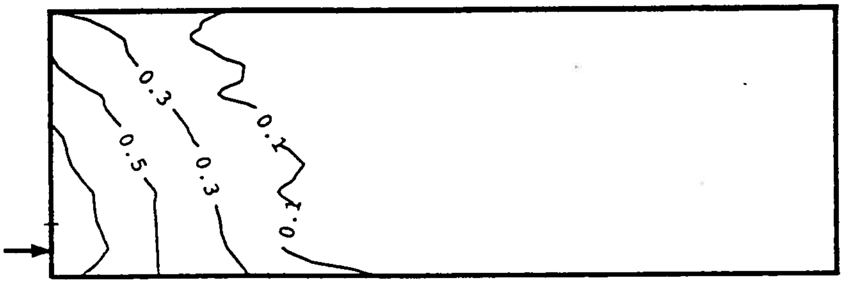
1000 kg = 1 t

Figure 4.4
CO_2 Saturation Contours for Numerical Run CO2_6

Location of Aquifer Outflow Boundary = 5 km

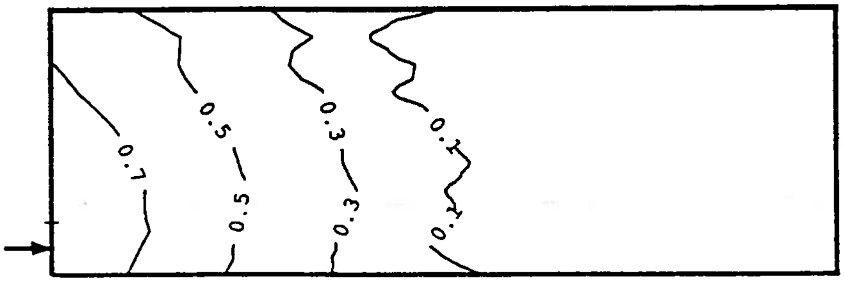
Injector radius = 3"   Injector Completion = 11 m (Bottom)

Vertical Dimension = 55 m   Horizontal Dimension = 650 m

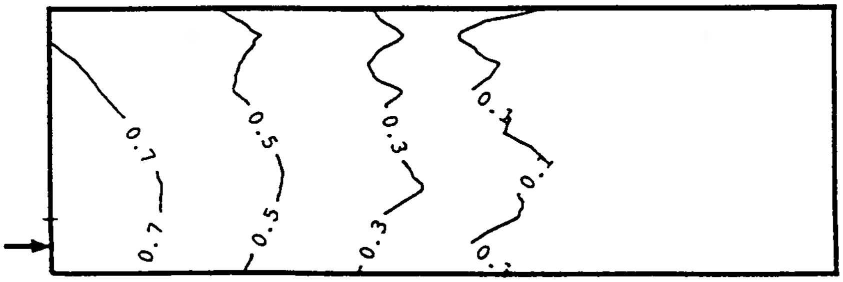


(a) after 5 years

(b) after 10 years



(c) after 20 years



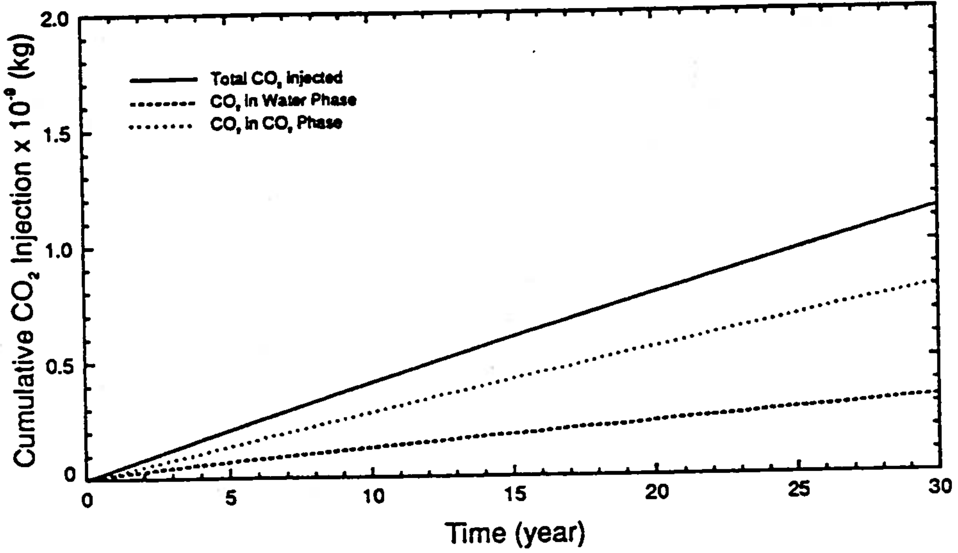
(d) after 30 years

Figure 4.5
CO_2 Injection for Numerical Run CO2_7

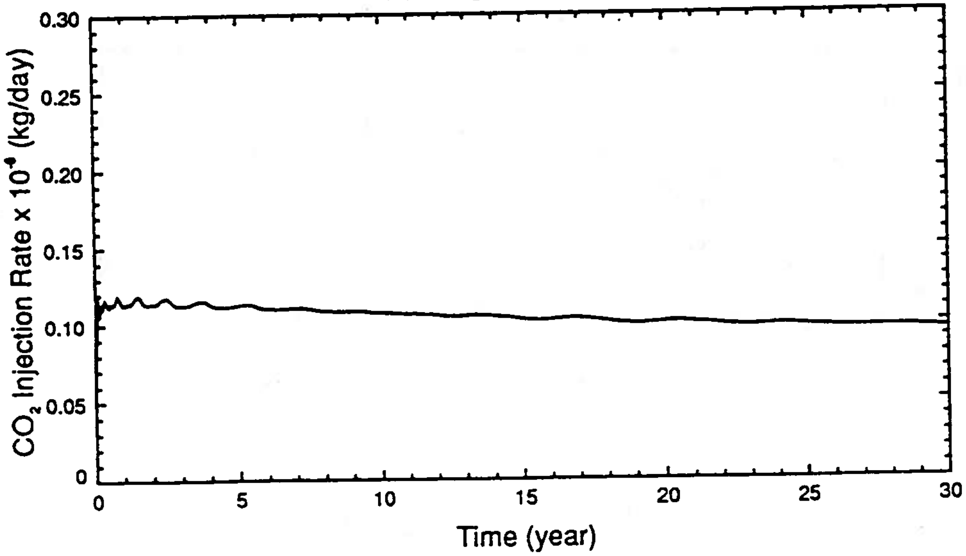
Location of Aquifer Outflow Boundary = 0.65 km

Injector Radius = 3"   Injector Completion = 11 m (Bottom)

(a) Cumulative CO_2 Injection



(b) CO_2 Injection Rate



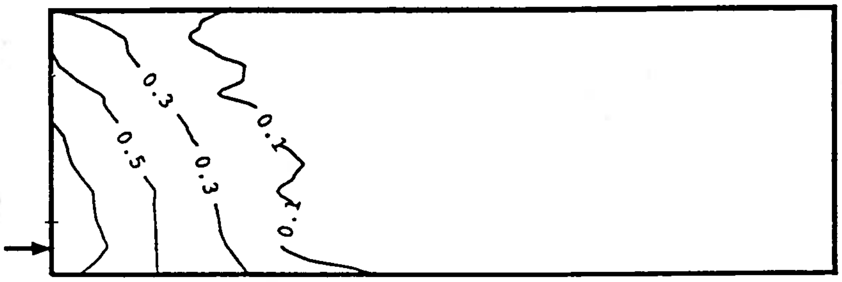
1000 kg = 1 t

Figure 4.6
CO_2 Saturation Contours for Numerical Run CO2_7

Location of Aquifer Outflow Boundary = 0.65 km

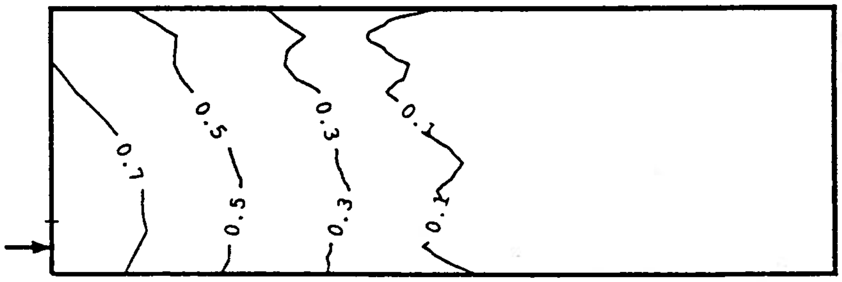
Injector radius = 3"   Injector Completion = 11 m (Bottom)

Vertical Dimension = 55 m   Horizontal Dimension = 650 m

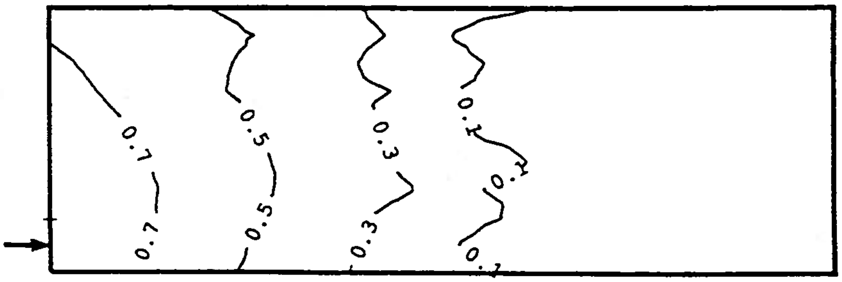


(a) after 5 years

(b) after 10 years



(c) after 20 years



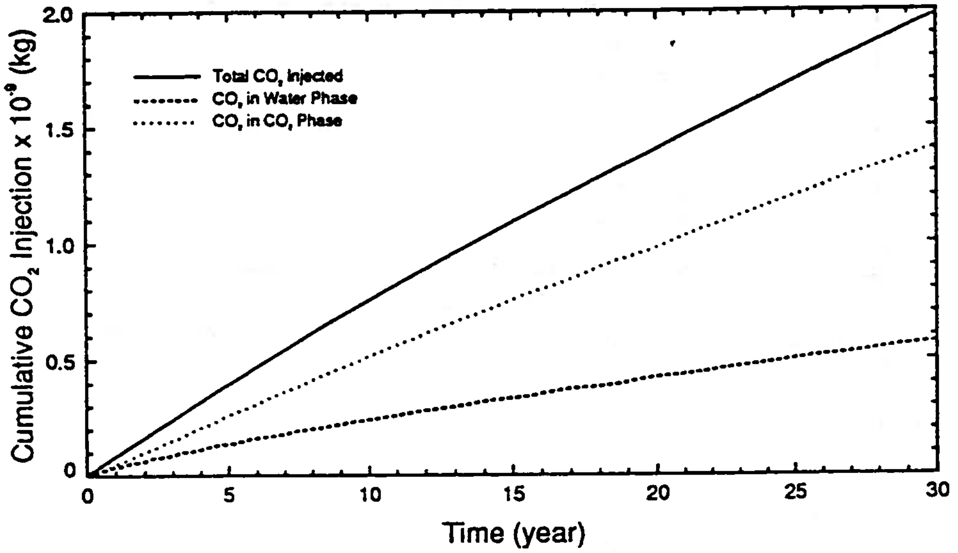
(d) after 30 years

Figure 4.7
CO_2 Injection for Numerical Run CO2_8

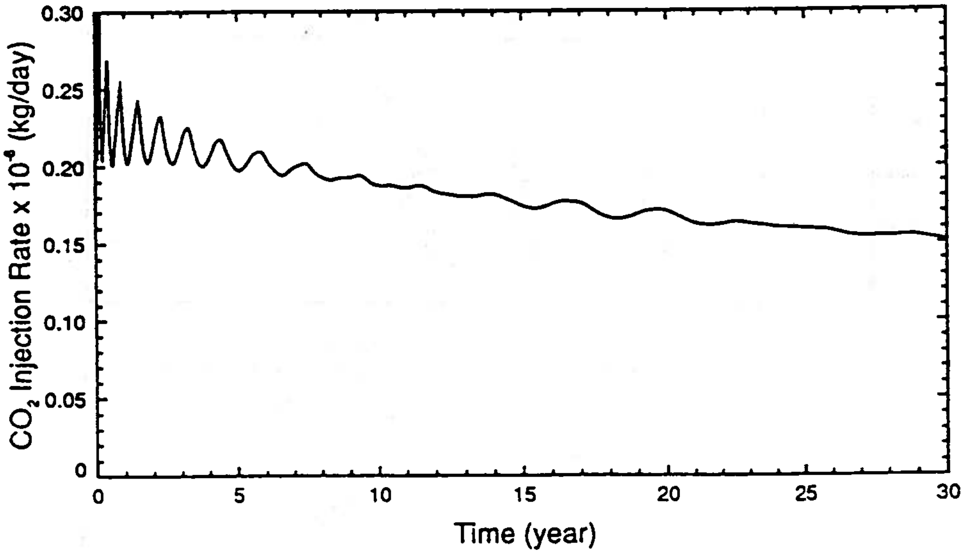
Location of Aquifer Outflow Boundary = 0.65 km

Injector Radius = 3"   Injector Completion = 55 m

(a) Cumulative CO_2 Injection



(b) CO_2 Injection Rate



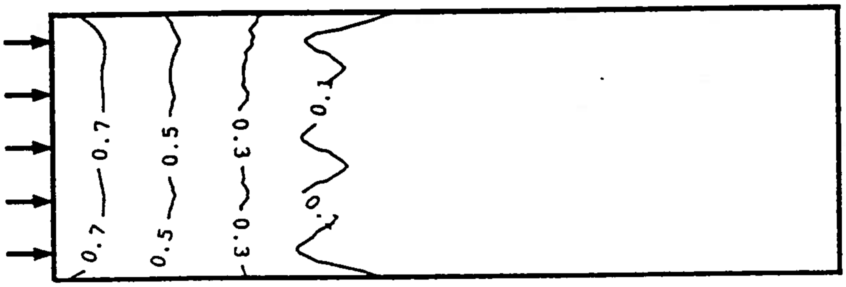
1000 kg = 1 t

Figure 4.8
CO_2 Saturation Contours for Numerical Run CO2_8

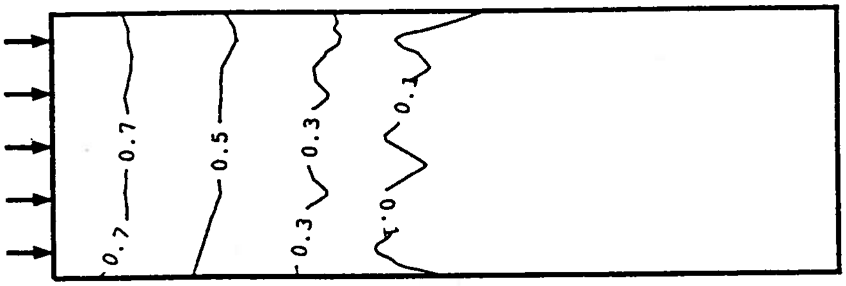
Location of Aquifer Outflow Boundary = 0.65 km

Injector radius = 3"   Injector Completion = 55 m

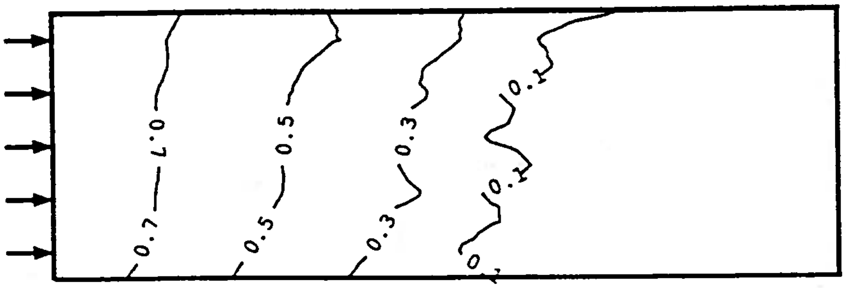
Vertical Dimension = 55 m   Horizontal Dimension = 650 m



(a) after 5 years



(b) after 10 years



(c) after 20 years

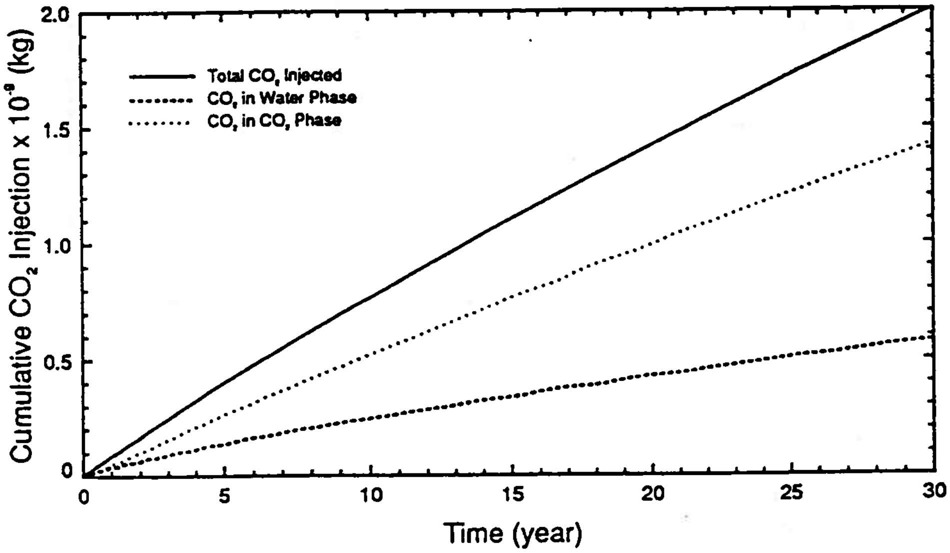
(d) after 30 years

Figure 4.9
CO_2 Injection for Numerical Run CO2_9

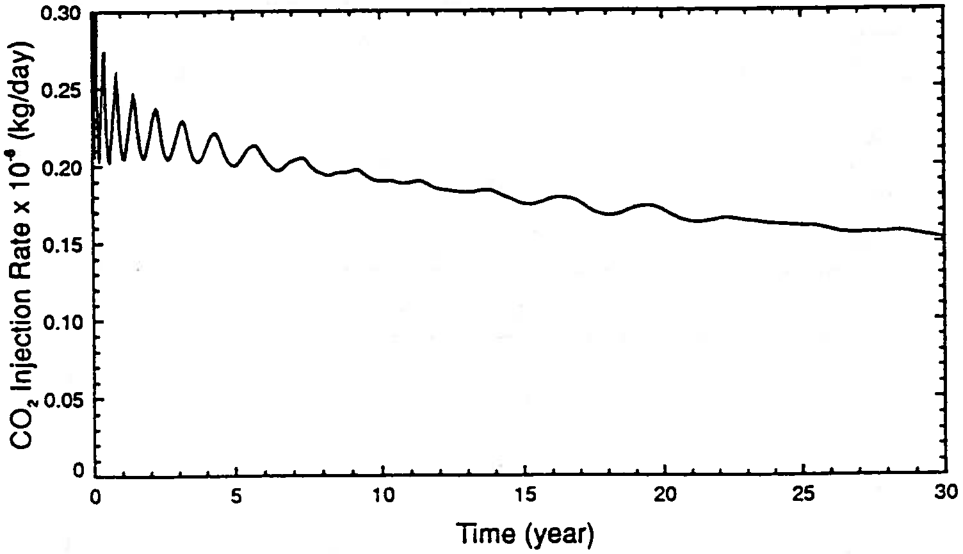
Location of Aquifer Outflow Boundary = 0.65 km

Injector Radius = 4"   Injector Completion = 55 m

(a) Cumulative CO_2 Injection



(b) CO_2 Injection Rate



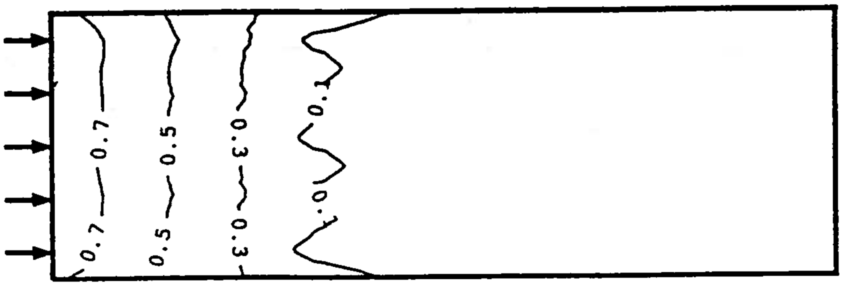
1000 kg = 1 t

Figure 4.10
CO_2 Saturation Contours for Numerical Run CO2_9

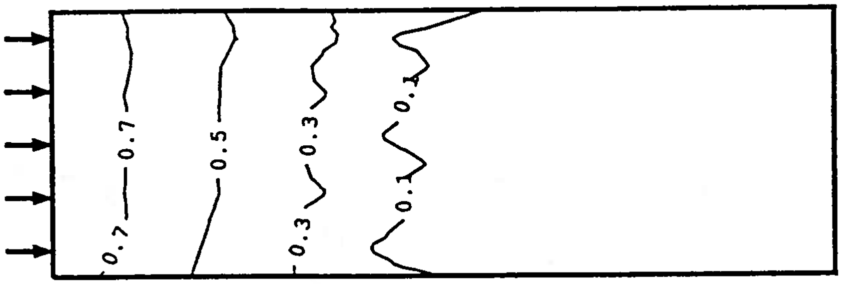
Location of Aquifer Outflow Boundary = 0.65 km

Injector radius = 4"   Injector Completion = 55 m

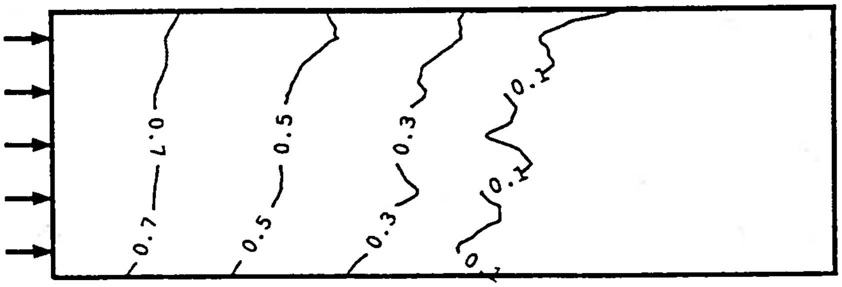
Vertical Dimension = 55 m   Horizontal Dimension = 650 m



(a) after 5 years



(b) after 10 years



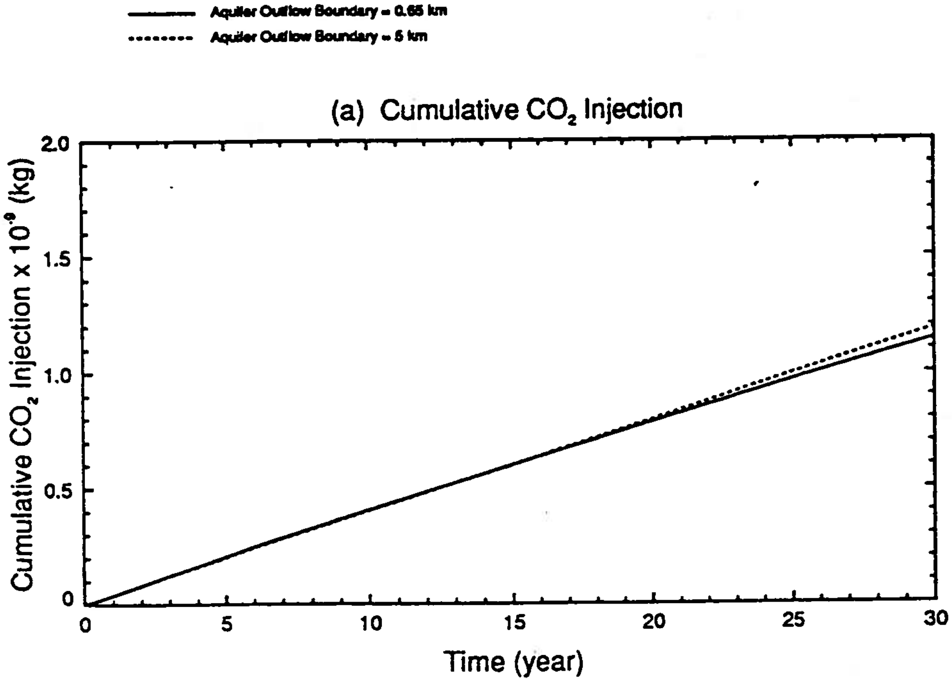
(c) after 20 years

(d) after 30 years

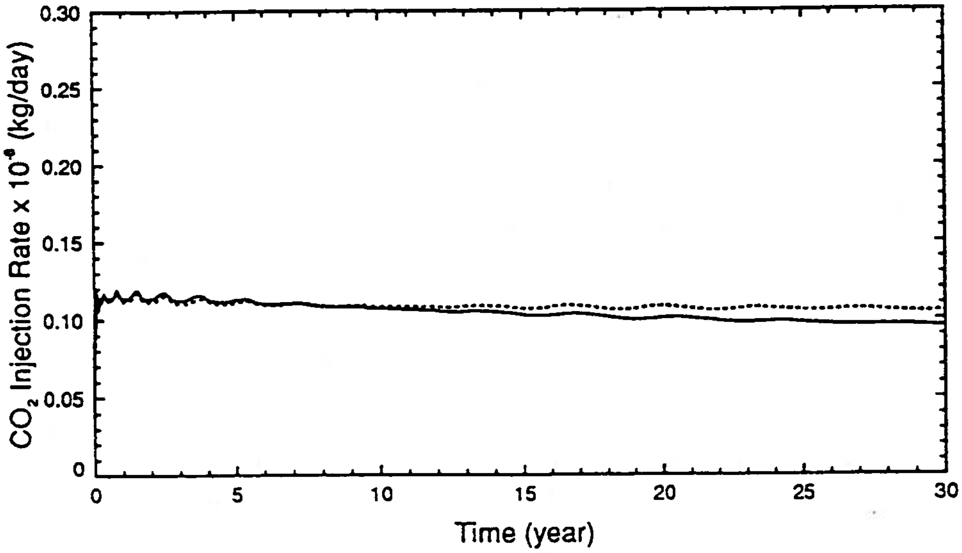
Figure 4.11
Effect of Aquifer Outflow Boundary Location on CO_2 Injection

Injector Radius = 3"   Injector Completion = 11 m (Bottom)

(a) Cumulative CO_2 Injection



(b) CO_2 Injection Rate



1000 kg = 1 t

Figure 4.12
Effect of Aquifer Outflow Boundary Location on Pressure Distribution After 30 Years

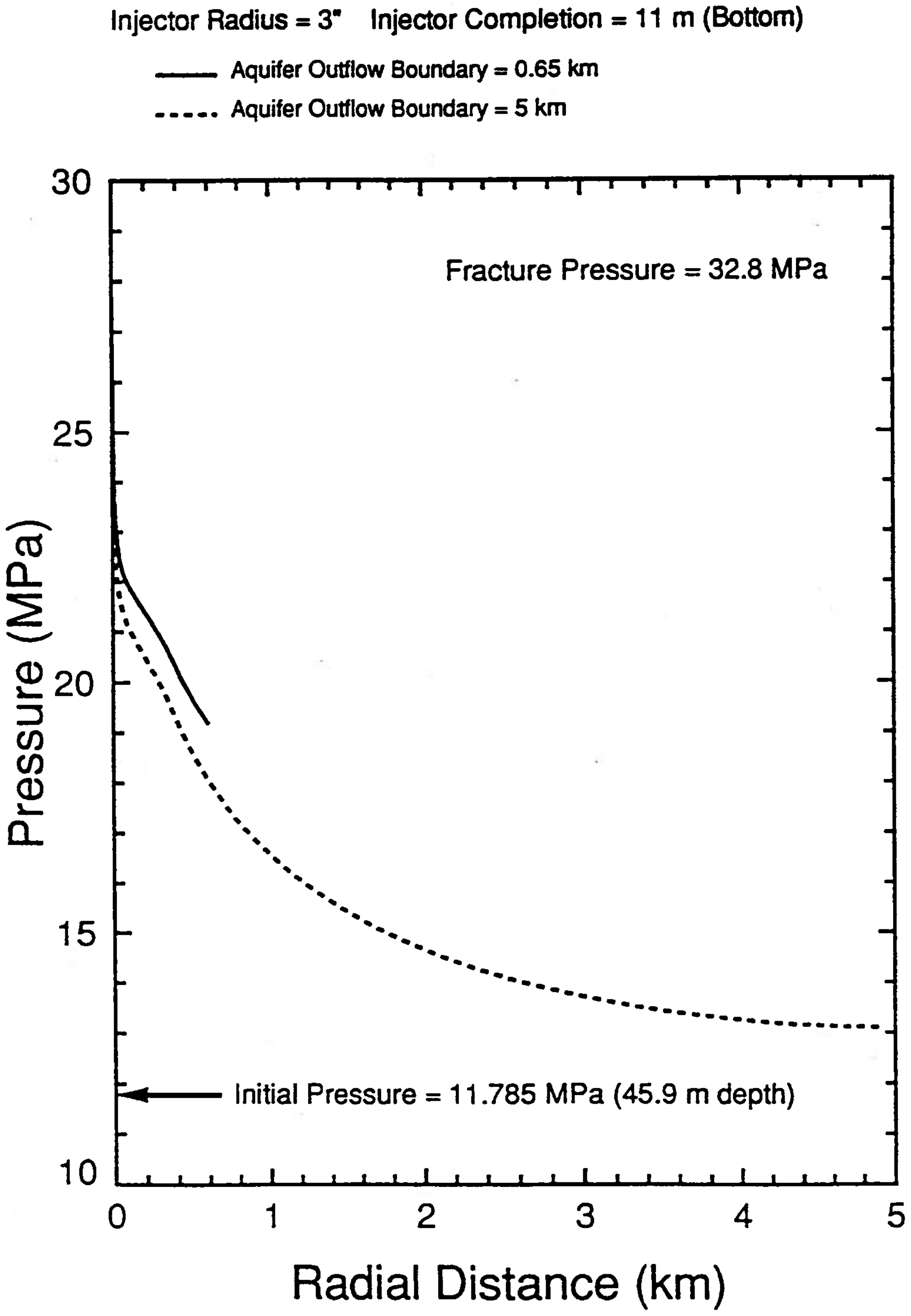


Figure 4.13
Average Water Velocity at 5 km from Injector (Run CO2_6)

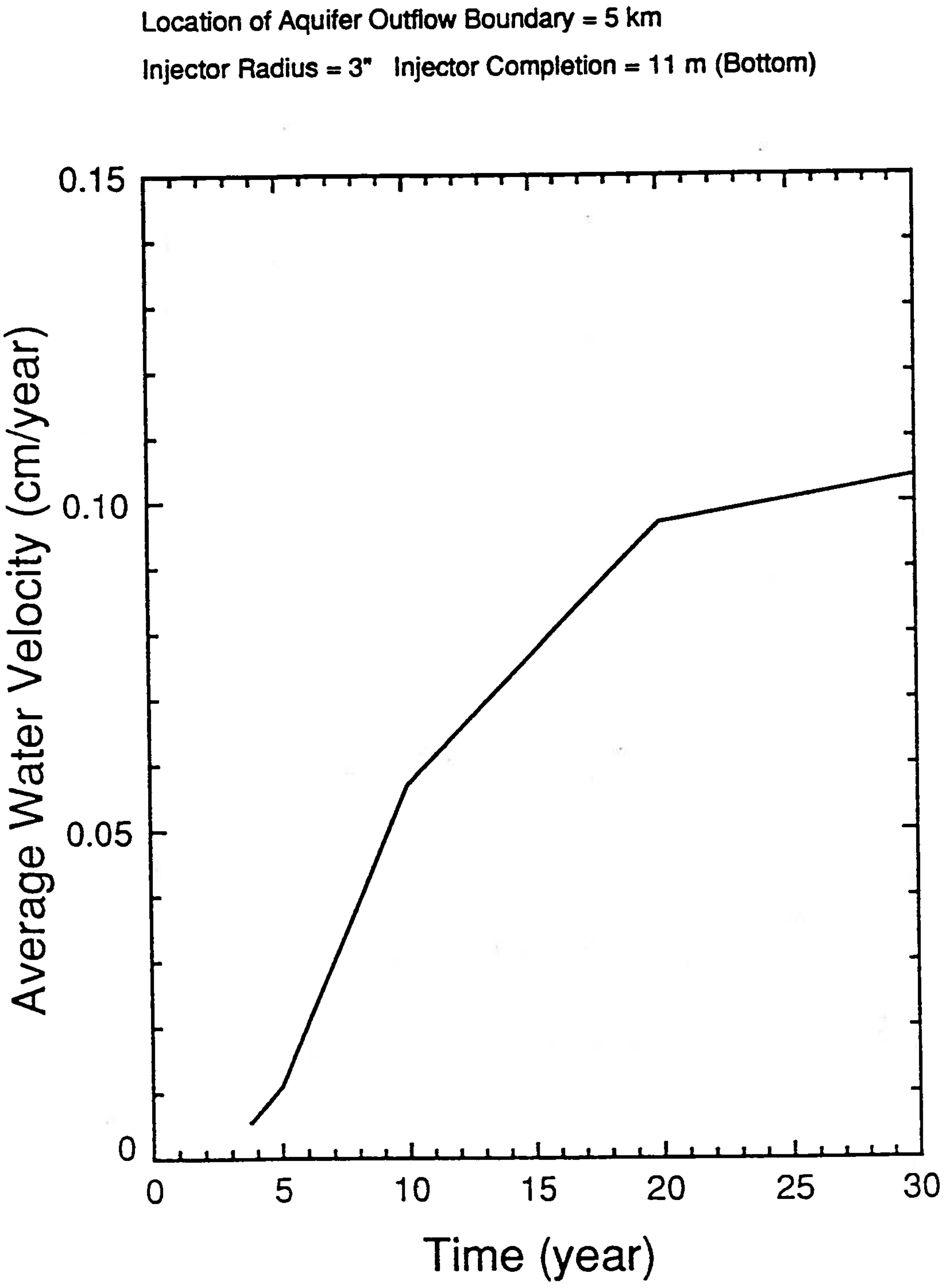
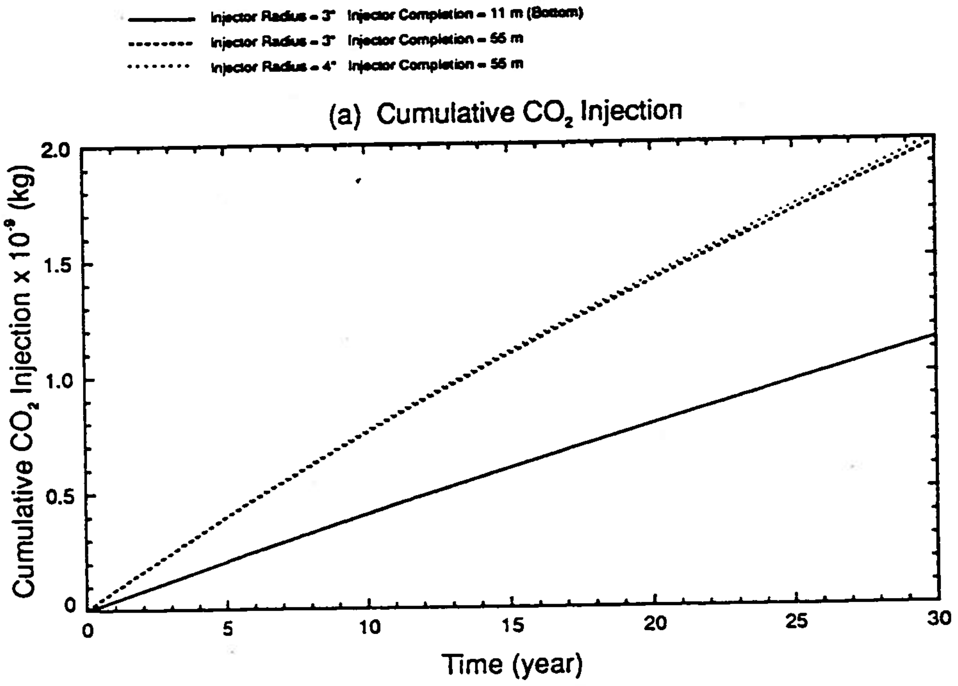


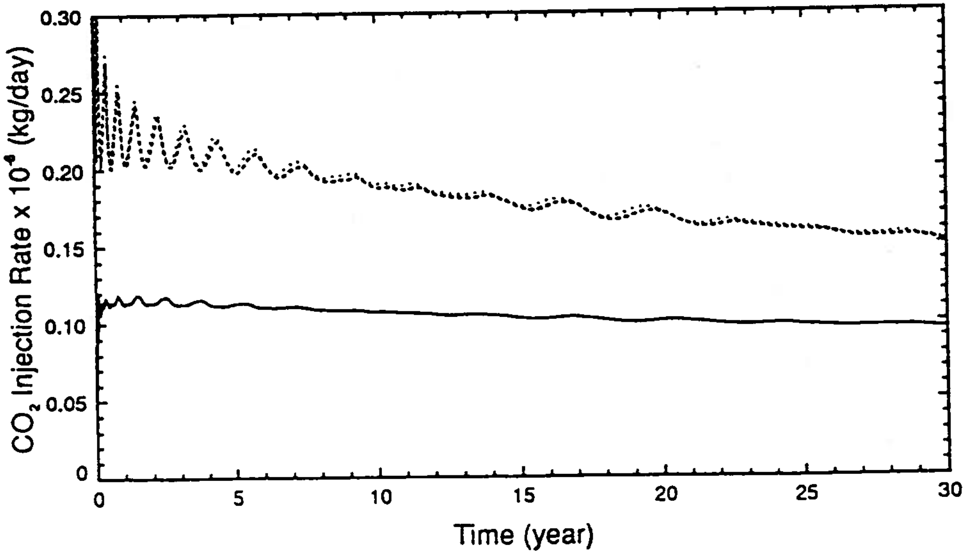
Figure 4.14
Effect of Injector Radius and Completion on CO_2 Injection

Location of Aquifer Outflow Boundary = 0.65 km



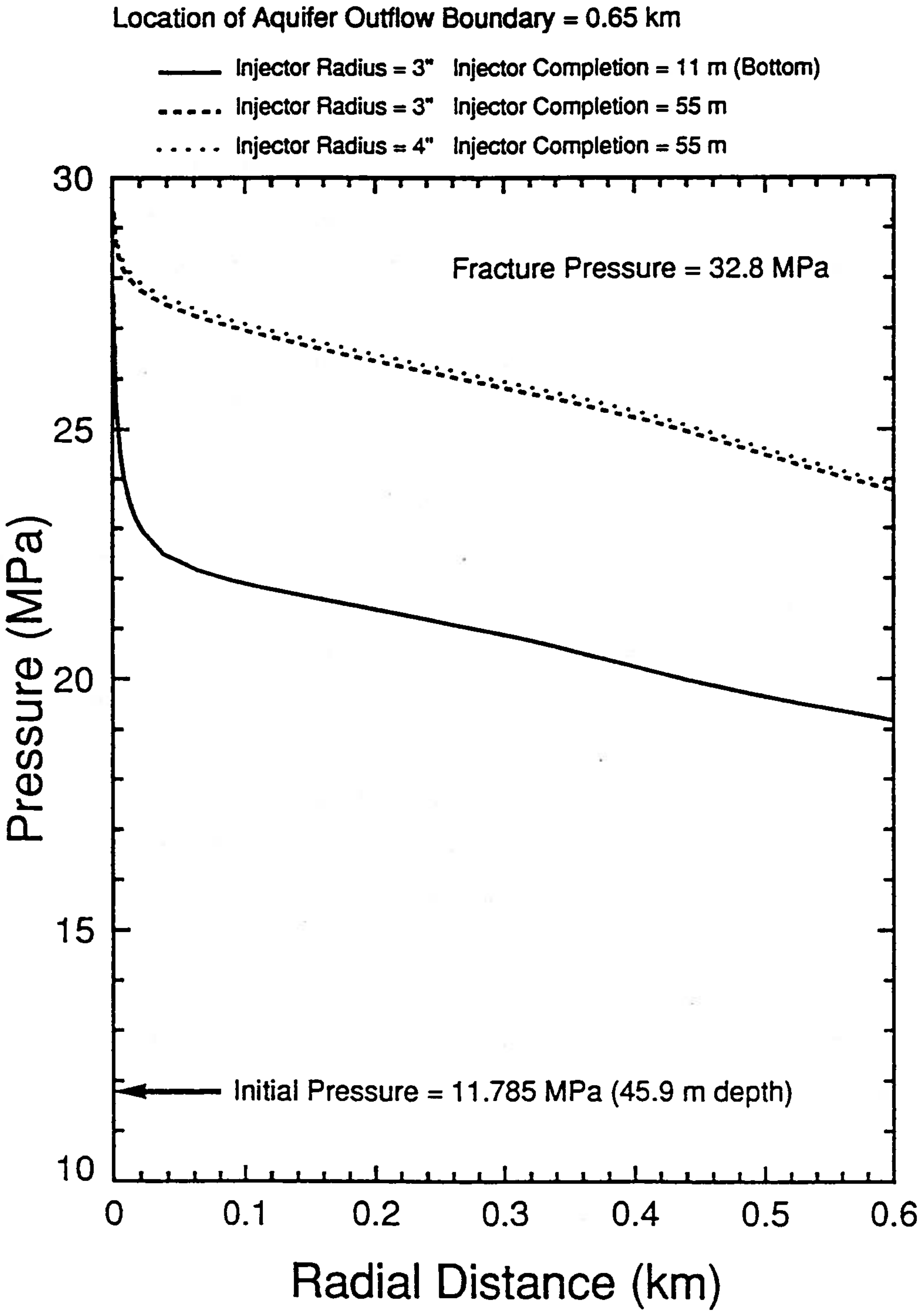
(a) Cumulative CO_2 Injection

(b) CO_2 Injection Rate



1000 kg = 1 t

Figure 4.15
Effect of Injector Radius and Completion
on Pressure Distribution After 30 Years



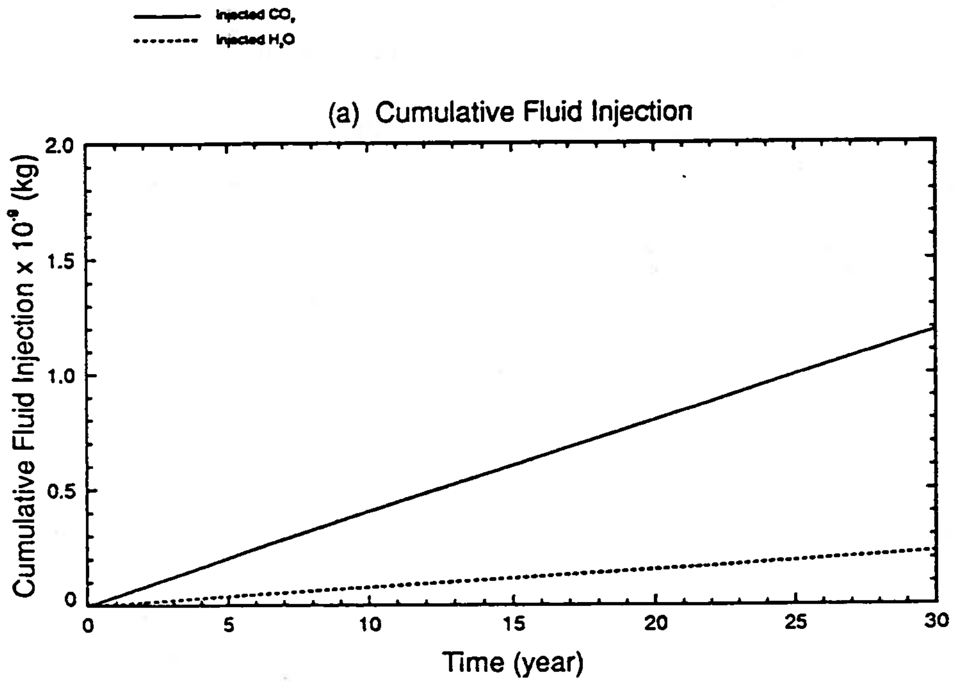
The effect of injected fluid could be studied by comparing the results from runs CO2_6 and H2O_4. As shown in Figure 4.16, under the same operating conditions, the amount of CO_2 injected was almost 5.5 times that of water mainly because the viscosity of CO_2 was almost two orders of magnitude lower than that of water. This indicated that an alternative by dissolving CO_2 into water first before injection was not as feasible as injecting the CO_2 under supercritical conditions.

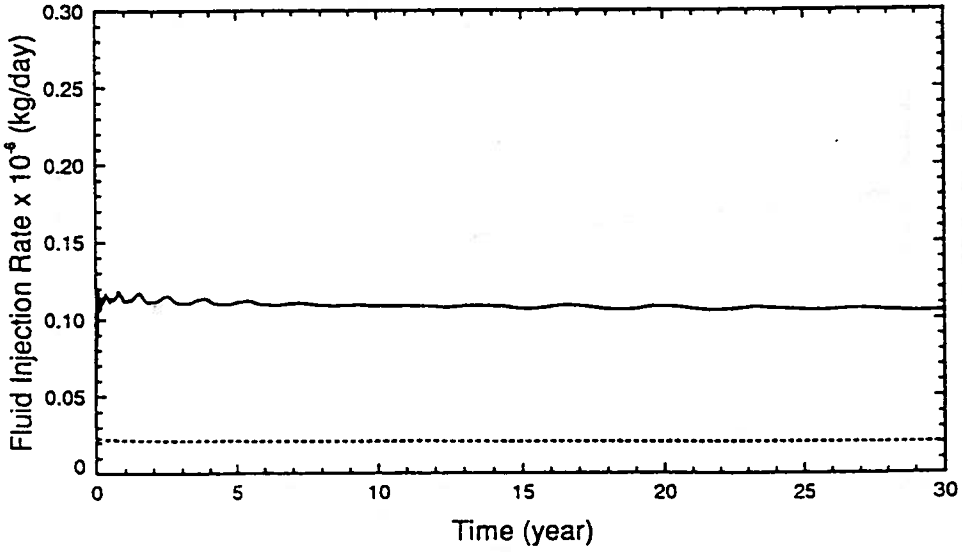
The effect of absolute permeability of the aquifer could be studied by comparing the results from runs CO2_8 and CO2_12. Numerical predictions of cumulative CO_2 injection, CO_2 injection rate, CO_2 saturation contours and pressure distribution as a function of time for run CO2_12 are given in Figure 4.17-4.21. As shown in Figure 4.17, by increasing the absolute permeabilities in all directions by 10 times, the average CO_2 injection rate increased from 180 t/day (Figure 4.14) to 1735 t/day. Due to this high injection rate, CO_2 override was significant and CO_2 propagated almost 2 km away from the injector after 30 years (see Figure 4.18). Even 10 years after the shut-in of the injector, the profile of the CO_2 saturation remained almost the same (see Figure 4.19). Under the same operating conditions, the aquifer with a higher absolute permeability (see radial distance = 0.6 in Figure 4.20) pressurized faster than the aquifer with a lower absolute permeability (Figure 4.15). After the shut-in of the injector, the aquifer depressurized rather slowly (Figure 4.21). Even 10 years after the shut-in of the injector, the pressure at a depth of 49.5 m from the top of the aquifer was approximately 19 MPa compared to the initial value of 11.785 MPa. At the high CO_2 injection rate, the average water rate due to CO_2 injection at 5 km from the injector reached as high as 28 cm/year as shown in Figure 4.22. Even 10 years after the shut-in of the injector, this water rate only reduced to 10 cm/year. This indicated that the CO_2 disposal operation in a relatively high permeability aquifer (13 mD) had a significant effect on the natural flow of the aquifer even 5 km away from the injector.

Figure 4.16
Effect of Injected Fluid on CO_2 Injection

Location of Aquifer Outflow Boundary = 5 km

Injector Radius = 3"   Injector Completion = 11 m (Bottom)


(a) Cumulative Fluid Injection


(b) Fluid Injection Rate

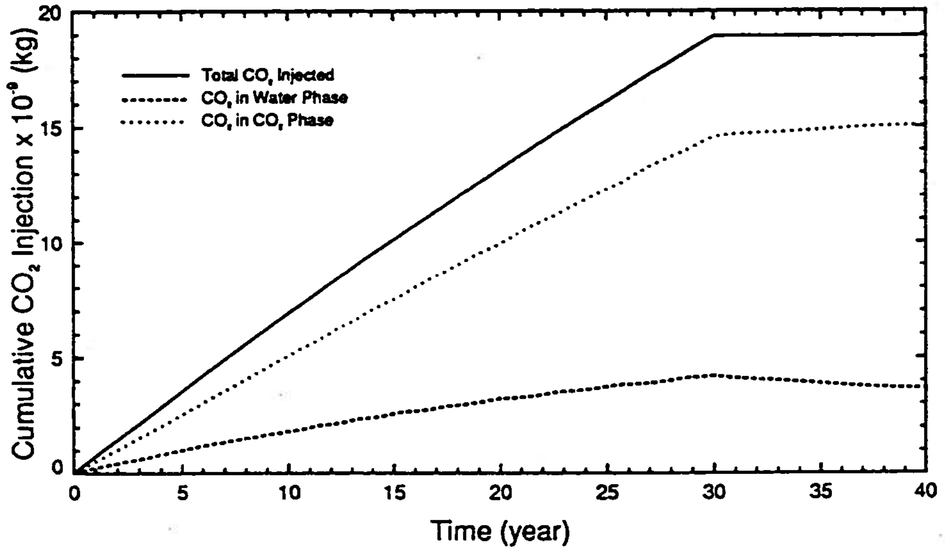
1000 kg = 1 t

Figure 4.17
CO_2 Injection for Numerical Run CO2_12

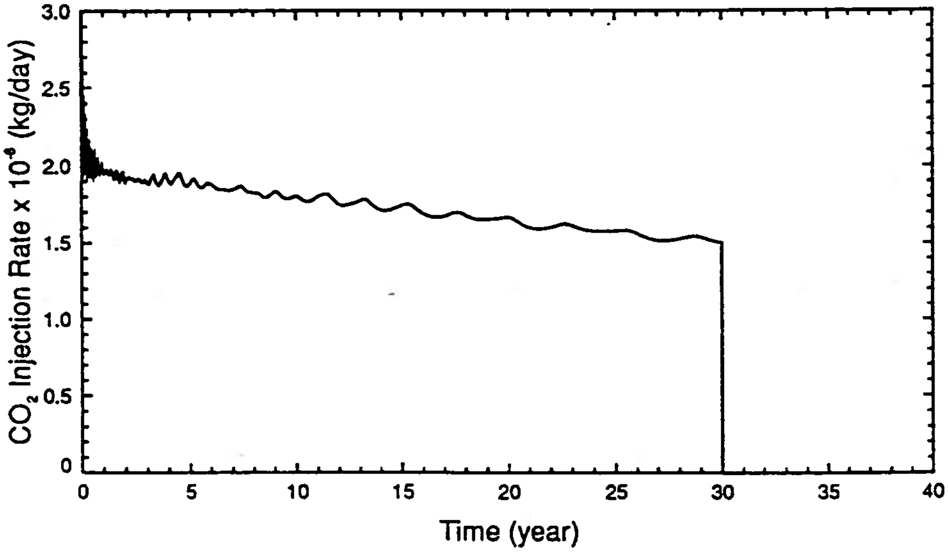
Location of Aquifer Outflow Boundary = 5 km

Injector Radius = 3"   Injector Completion = 55 m

(a) Cumulative CO_2 Injection



(b) CO_2 Injection Rate



1000 kg = 1 t

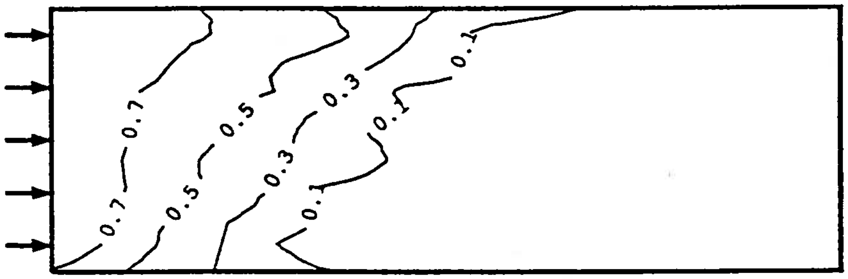
Figure 4.18
CO_2 Saturation Contours for Numerical Run CO2_12

Location of Aquifer Outflow Boundary = 5 km

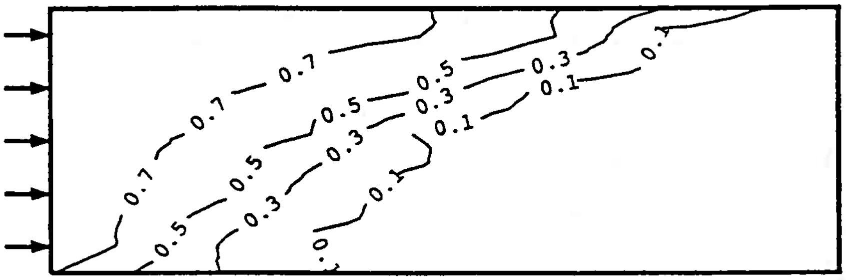
Injector radius = 3"   Injector Completion = 55 m

Vertical Dimension = 55 m   Horizontal Dimension = 2 km

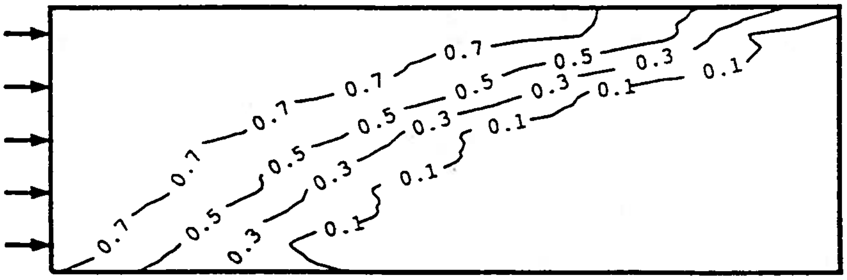
(a) after 5 years



(b) after 10 years



(c) after 20 years



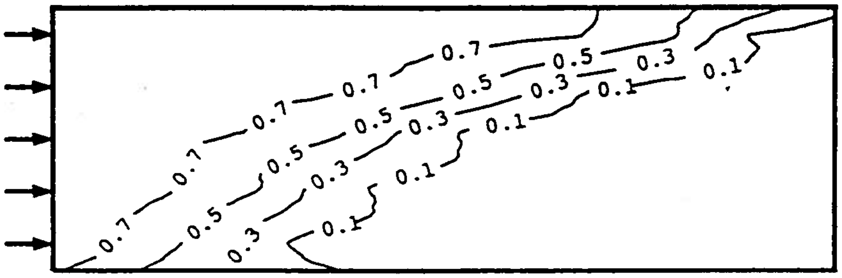
(d) after 30 years

Figure 4.19
CO_2 Saturation Contours for Numerical Run CO2_12
(After Shut-in)

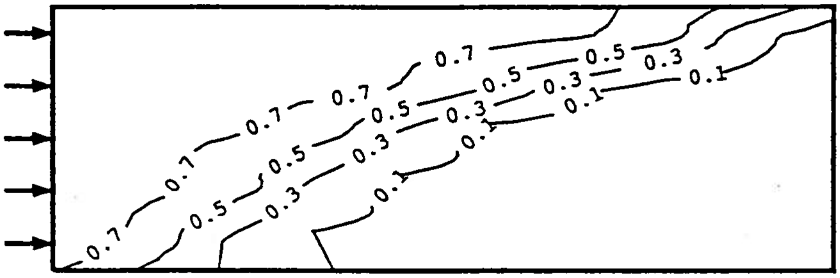
Location of Aquifer Outflow Boundary = 5 km

Injector radius = 3"   Injector Completion = 55 m

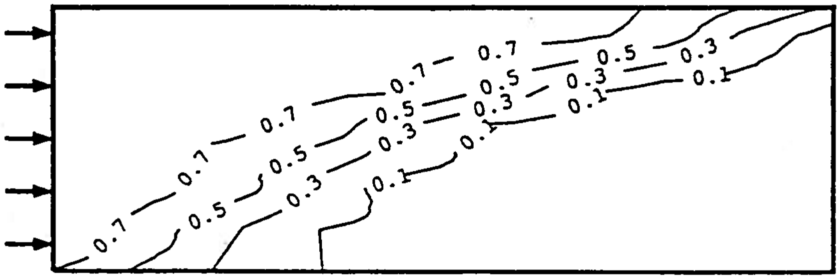
Vertical Dimension = 55 m   Horizontal Dimension = 2 km



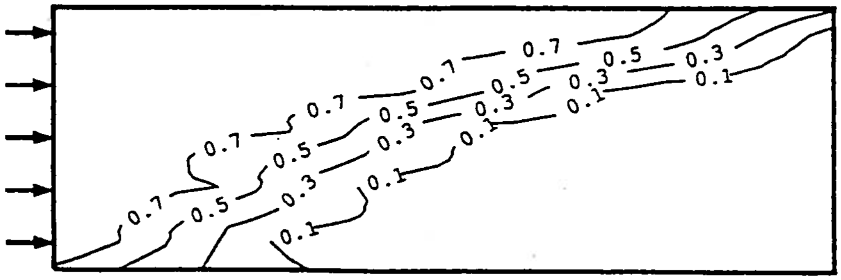
(a) after 30 years (injector shutin)



(b) after 32 years



(c) after 35 years



(d) after 40 years

Figure 4.20
Pressure Distribution for Numerical Run CO2_12

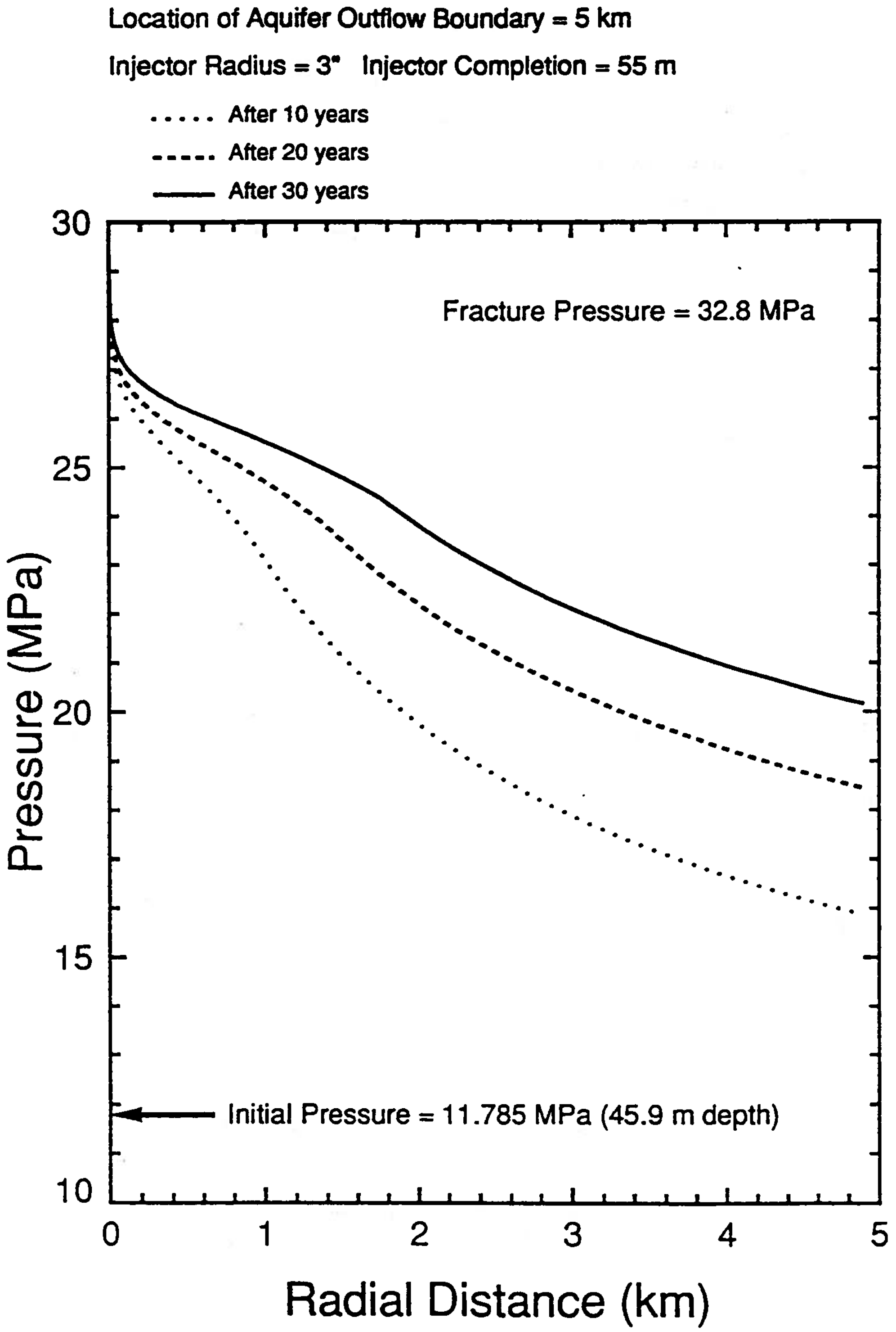


Figure 4.21
Pressure Distribution for Numerical Run CO2_12
(After Shut-in)

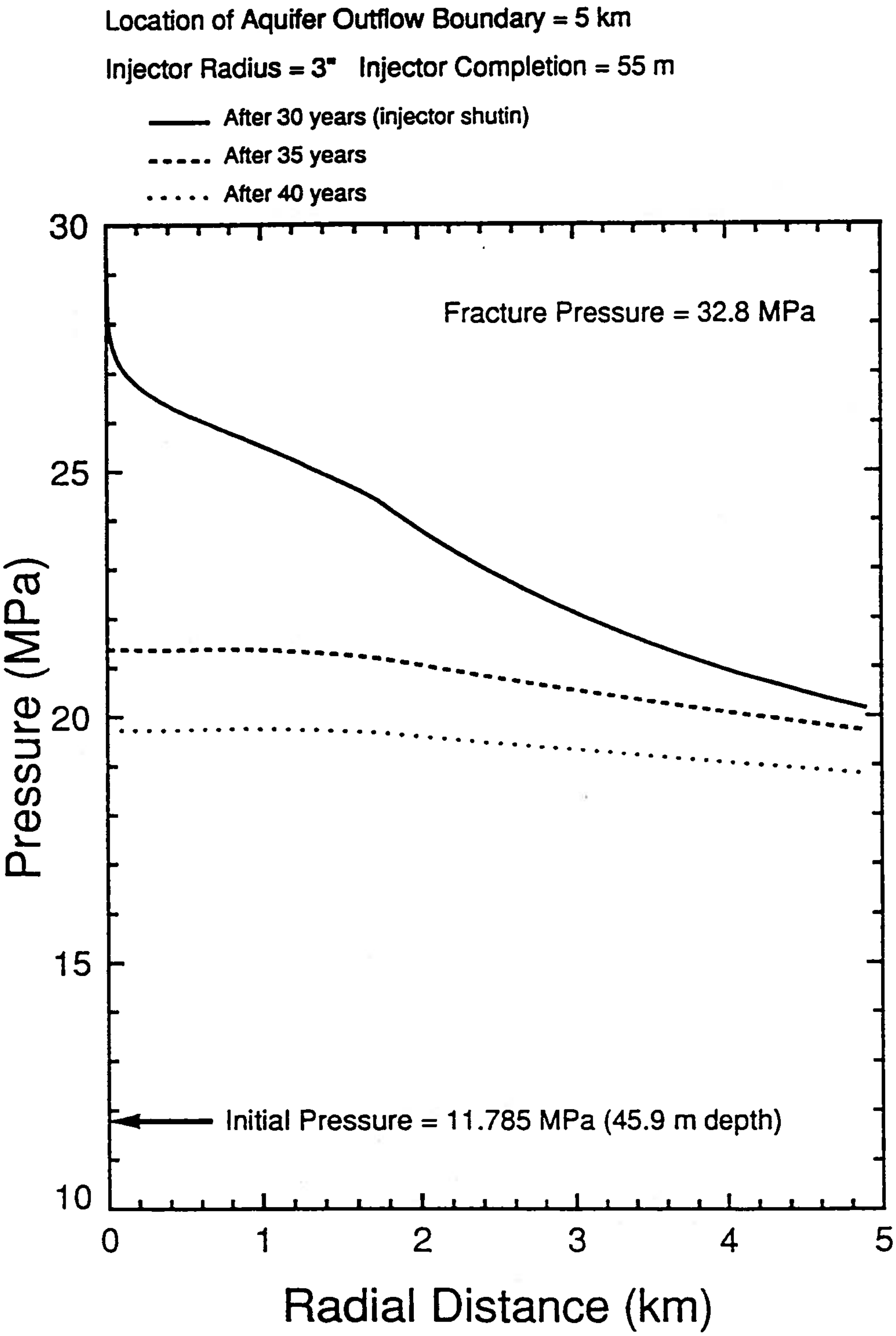
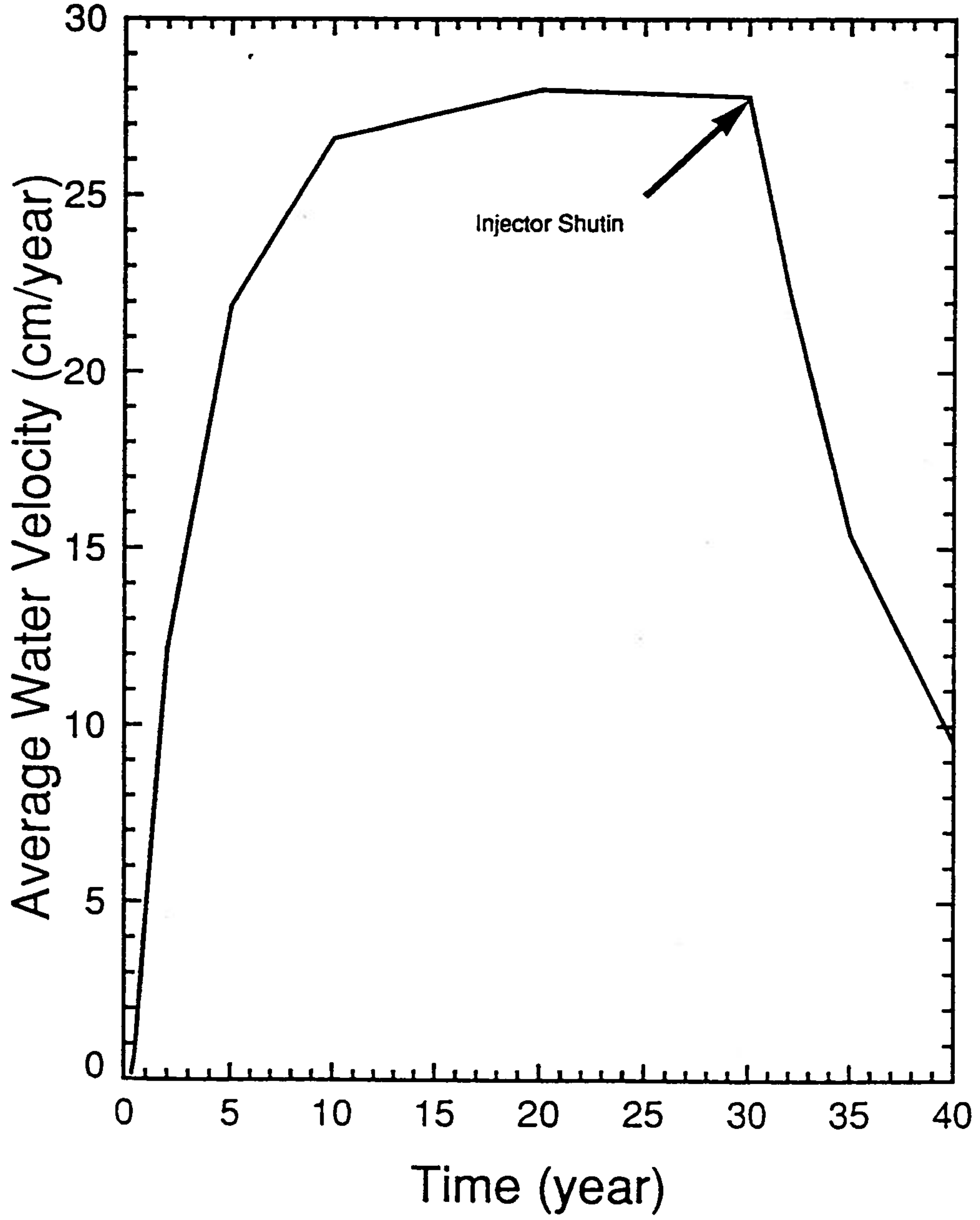


Figure 4.22
Average Water Velocity at 5 km from Injector (Run CO2_12)

Location of Aquifer Outflow Boundary = 5 km

Injector Radius = 3"   Injector Completion = 55 m



5.0 MODELLING OF CO_2 RESERVOIR REACTIONS

5.1 PREAMBLE

Geological CO_2 sinks, depending upon the time scale, may be classified as reactive or inert. Clearly, reactive sinks are the most effective for permanent, long-term disposal. Injection into aquifers, and the subsequent dissolution into the water, increases the reactivity of CO_2 considerably. In addition, flow through porous media in the crust promotes natural mixing and exposure of the dissolved CO_2 to additional grain surfaces where reactions can take place.

In this section, the primary focus is on the generic documentation of the enhancement of CO_2 capture by aquifer water-rock interaction. We distinguish three scenarios in the use of aquifers for the disposal of CO_2:

1) The solution of CO_2 into a formation fluid in the absence of formation mineralogy;

2) The solution of CO_2 and reaction with the minerals present in a carbonate aquifer;

3) The solution of CO_2 and reaction with the minerals in a dominantly siliciclastic aquifer.

These scenarios are tested on aquifers in an area close to the Sundance and Genesee power plants.

5.2 FORMATION WATER CHEMISTRY ADJUSTMENTS

The formation water analyses described earlier are often limited with sodium or chloride values calculated by difference. Silica and other potentially important components were never measured. Even in the best analyses, the only anions directly measured were chloride and sulphate; with a total alkalinity assumed to represent carbonate and bicarbonate ion concentrations. This assumption can lead to significant error in the calculated amounts of total inorganic carbon (TIC) when other anions (ammonium and organic acids among others) are present.

Many of the samples are above or near equilibrium with atmospheric carbon dioxide partial pressure, thus implying that the formation water sample has probably released carbon dioxide between the time of sampling and the time of analysis. A number of samples are also supersaturated with carbonate minerals, notably calcite. This is impossible in the formation due to the extremely fast rates of reactions of carbonate minerals and the low residency time of the formation waters. Corrections for these two *sampling* errors can be undertaken if sufficient information is known or can be assumed.

Two waters (brackish and a brine) were chosen as the basis for the modelling, each representing an extreme in TDS (i.e. approximately 4,000 versus 100,000 ppm). Sodium, potassium, calcium, magnesium and chloride are all more than an order of magnitude higher in the brine while sulphate is three times higher and bicarbonate is actually lower (Table 5.1). The actual composition chosen for modelling depended on corrections as discussed below and simplification of the formation water chemistry pertinent to the end member mineralogy being modeled.

Representative Brine H_2O

```
                  ------------------------------
                 | AGSWDB WATER ANALYSIS REPORT |
                  ------------------------------

AGSWDB Well site identifier (SITID):      73666   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):  -1545304

CORE LABORATORIES CANADA LT.                      Lab. Sample ID. C84-5196-4

Well identifier  Well name                                KB elev. Gr. elev
0495051416020    PROPHET ET AL PEMBINA 16-14-49-5            799.60    795.60

Interval Sampled from:   1739.00  to:   1746.00 meters KB

Formation Sampled: MISS SYS

Sample produced by: DST #    1                    Sampling point:DOWN HOLE SAMPLE
  DST Recovery
        58.00 M   CLEAN OIL
       258.00 M   OIL- AND GAS-CUT SALT WATER
 Date:   Sampled:  1984/06/08  Received: 1984/06/18  Analyzed: 1984/06/21

              CATIONS                                        ANIONS
|----------------------------------|   |---------------------------------------|
|  ION  |      mg/l      | %MEQ  | MEQ/L |   |  ION  |      mg/l      | %MEQ  | MEQ/L |
|----------------------------------|   |---------------------------------------|
|Na     |        33900.| 41.029| 1474.6|   |Cl     |        63000.| 49.444| 1777.0|
|K      |          813.|  0.579|   20.8|   |HCO3   |          944.|  0.430|   15.5|
|Ca     |         4084.|  5.670|  203.8|   |SO4    |          689.|  0.399|   14.3|
|Mg     |         1069.|  2.448|   88.0|   |       |              |       |       |
|       |              |       |       |   |       |              |       |       |
|----------------------------------|   |---------------------------------------|

Specific gravity        1.0680 @  25. C   Refractive Index      1.34950 @  25. C
PH                        7.20 @  25. C   Resistivity ohm/m     0.07900 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:          34835.        Calculated TDS :            104141.
TDS by Evapor. @ 110 C:          116200.  TDS at Ignition :                101700.

Sample appearance:

A LYNES UNITED DOWNHOLE SAMPLER 214.WAS REC'D UNDER 689 KPA PRESSURE.RECOVERED
 FROM THE CHAMBER WAS GAS AND 1.9 L OF OIL STAINED MUDDY SALT WATER.

Remarks:

Fe PRESENT
                        ------------------------------
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Representative Brackish H_2O

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                  ------------------------------
                 | AGSWDB WATER ANALYSIS REPORT |
                  ------------------------------

AGSWDB Well site identifier (SITID):      80735   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):      44545

CHEMICAL & GEOLOGICAL LAB LTD                     Lab. Sample ID. E80-13493-3

Well identifier  Well name                                KB elev. Gr. elev
0515040313000    ANDEX ET AL HIGHVALE 13-3-51-4              764.30    760.20

Interval Sampled from:   1578.00  to:   1586.00 meters KB

Formation Sampled: OSTRACODE

Sample produced by: DST #    1                    Sampling point:0 M ABO TOOL
  DST Recovery
       948.00 M   CLEAN OIL
         2.00 M   SALT WATER
 Date:   Sampled:  1980/11/16  Received: 1980/11/25  Analyzed: 1980/12/16

              CATIONS                                        ANIONS
|----------------------------------|   |---------------------------------------|
|  ION  |      mg/l      | %MEQ  | MEQ/L |   |  ION  |      mg/l      | %MEQ  | MEQ/L |
|----------------------------------|   |---------------------------------------|
|Na     |         1715.| 48.734|   74.6|   |Cl     |         1717.| 31.639|   48.4|
|K      |           18.|  0.301|    0.5|   |HCO3   |         1434.| 15.353|   23.5|
|Ca     |           21.|  0.685|    1.0|   |SO4    |          222.|  3.020|    4.6|
|Mg     |            5.|  0.269|    0.4|   |       |              |       |       |
|       |              |       |       |   |       |              |       |       |
|----------------------------------|   |---------------------------------------|

Specific gravity        1.0030 @  25. C   Refractive Index      1.33360 @  25. C
PH                        8.40 @  21. C   Resistivity ohm/m     1.36000 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:           1726.        Calculated TDS :              4397.
TDS by Evapor. @ 110 C:            4530.  TDS at Ignition :                  4125.

Remarks:

FE NIL.
                        ------------------------------
```

Table 5.1
Representative Formation
Water Analyses of a
Dilute Water and Brine

A number of corrections were made to these two waters. If a carbonate mineral was supersaturated, the TIC (total inorganic carbon) levels were increased through the addition of carbon dioxide until the mineral was at equilibrium with the solution. This modified the formation pH to more acid conditions. The concentration of missing components, if considered significant, was estimated by calculating what concentration would be in equilibrium with the reservoir mineralogy. For example, the concentration of dissolved silica was estimated by assuming equilibrium with quartz, yielding a concentration of approximately 10^{-4} moles per litre.

These corrections to the brackish and brine formation waters provided the basis of the fluid compositions for the modelling. When modelling the interactions between the injected CO_2, the formation mineralogy and a formation fluid, the formation fluid should be in equilibrium with the formation mineralogy. As is discussed in more detail below, a range of stoichiometric formation mineralogies was used for the simulations, which were not necessarily in equilibrium with the corrected brackish and brine formation waters. When this occurred, the corrected brine and brackish formation waters were further modified in order to be closer to equilibrium with the formation mineralogies. These modifications would not be necessary if the appropriate formation water and the mineralogy of the injection horizon were being used for a site-specific study.

5.3 MODELLING OF WATER-ROCK REACTION

Modelling of water-rock reactions was carried out at an aquifer temperature of 25°C on stoichiometric end member mineralogies (i.e. pure Na-, K-, Ca- and Mg- minerals) using the mass transfer geochemical computer code PATH.ubc (Perkins, 1980) and GeoCalc (Brown et al., 1989). PATH.ubc calculates the path of water-rock reaction for a given set of reactants as a function of the progress variable, 'XI' which is proportional to the log of time. 'XI' is used to define the molar amount of reactant phases added to the aqueous phase per step. This effectively results in linear kinetics. The relative reaction rate for each reactant are defined by a user-specified factor with the default of one normally being used. The modelling does not take into account the effects of solid solution on the size of each of the mineral stability fields, even though the end-member feldspars, zeolites and clays generally do form solid solutions with the other end-members in the same mineral group. The reason for this assumption is simplicity; the thermodynamic data for solid solution minerals is non-existent or poor, and the numerical methods for calculating dynamic equilibria for solid solution minerals are intractable. These reasons also explain why the GeoCalc and PATH.ubc calculations do not include the effects of solid solution equilibria.

The initial conditions for PATH.ubc comprise the formation water chemistry, the number of grams of each of the formation minerals in equilibrium with the formation water (equilibrium phases) and the reactant phases (CO_2 is a reactant phase in the context of the modelling). As 'XI' progresses, the reactants dissolve into the formation water, resulting in a different formation water composition. The change in formation water composition may be buffered by the precipitation (or dissolution) of the equilibrium phases or by the formation of new equilibrium phases. Often an equilibrium phase is formed but later completely reacts, and none is left in the system. PATH.ubc terminates when equilibrium has been achieved with all of the reactant phase(s) and/or when all of the reactant phase(s) have reacted.

Several formation water chemistries have been chosen to represent the spectrum of water chemistry as described above. The equilibrium phases used for the initial conditions were based upon the observed formation mineralogy, but modified to obtain the necessary *end member composition* constraints. The amount of equilibrium minerals present is calculated from the porosity. Assuming an average porosity of 10% and an average rock density of 2.5, there are approximately 22,000 grams of rock per 1000 grams of water. Even if the porosity is doubled to 20%, the weight of rock would only be reduced to 10,000 grams. For the former case, the presence of 5 wt% of a mineral phase would account for 1000 grams of that phase being contacted by 1000 grams of water.

Final equilibrium with the injected CO_2 is defined as when the partial pressure of CO_2 in equilibrium with the formation fluid is 15 MPa. This value was chosen as it is representative of the minimum injection pressure for liquid CO_2 necessary for injection into the deep aquifers below the Genesee and Sundance power stations.

5.4 CO_2 SOLUBILITY IN BRACKISH WATER AND IN BRINE

If carbon dioxide is dissolved into either a brine water (i.e. TDS is greater than 100,000 mg/l) or brackish water (i.e. TDS lies between 1000 and 10,000 mg/l) with no formation minerals present, no new minerals are precipitated. The water becomes more acidic and the amount of dissolved carbon dioxide is a function of pressure and fluid composition. A salting out effect occurs as the water becomes more concentrated. The basis for these results is shown through the following model simulations.

CO_2 was numerically dissolved stepwise into the brackish formation water of ionic strength 0.063 (Table 5.2) at 25°C. Figure 5.1, curve "a" (Figure 11.5.1a - note that Figures identified by the prefix '11' are found in Appendix 11.) shows the rise in CO_2 pressure as increments of CO_2 are added. The amount of CO_2 added is directly proportional to the progress variable, 'XI', as shown on Figure 11.5.1a. A CO_2 pressure of 15 MPa was reached after 4 moles of CO_2 had been added to each 1000 grams of water (compare Figures 11.5.1a and 11.5.1b). The change in the distribution of species in the formation water is plotted in Figure 11.5.1c. Bicarbonate ion is the dominant carbonate species in the formation water initially. As CO_2 is added, H_2CO_3 becomes dominant while the pH decreases; bicarbonate ion concentration remains nearly constant.

For the brine formation water (ionic strength 4.00), the total CO_2 added to reach a CO_2 pressure of 15 MPa is approximately 2 moles per 1000 grams of water (Figure 11.5.2); about one half the amount added to the brackish formation water. This *salting out effect* is due to the increasing importance of hydration with salt content. As the ionic strength of the formation water increases to that of a brine, the activity coefficient of H_2CO_3 increases from 1 to 2. Obviously to maximize CO_2 solubility, dilute formation waters are favoured.

5.5 CO_2 SOLUBILITY IN CARBONATE AQUIFERS

If carbon dioxide is dissolved in a fluid in equilibrium with a carbonate formation (the formation mineralogy comprises calcite and/or dolomite, possibly with minor amounts of quartz present), the total amount of CO_2 dissolved into the fluid is greater than the previous case, but no new minerals are precipitated. In fact, the formation carbonate minerals dissolve into the fluid and partially neutralize the acid created by the addition of the carbon dioxide. The dominant reaction can be written as:

$$CO_2 + H_2O + \text{Calcite} = Ca^{++}\ (\text{ion}) + 2\ HCO_3^-\ (\text{ion})$$

Two aquifers were chosen to model this reaction: a pure dolomite-calcite aquifer and a dolomite-calcite-quartz aquifer. Both were reacted with the brackish formation water (Table 5.2). The pure dolomite-calcite aquifer is considered in Figure 5.2 (or Figure 11.5.3). The curves are almost identical to those of the pure formation water example (compare Figure 5.2a to Figure 5.1, curve "a") because only small amounts of calcite and dolomite have dissolved by the time equilibrium is reached (0.004 moles of dolomite and 0.05 moles of calcite; see Figure 5.2c (or Figure 11.5.3b2) and Table 5.2). This causes the concentration of bicarbonate ion to increase substantially (Figure 5.2b (or Figure 11.5.3c)) which results in an increase of approximately 1.5% or 0.06 moles of CO_2 gas dissolved (Figure 5.2d) compared to the pure formation water case. The amount of additional CO_2 which can be added to a calcite-dolomite-quartz aquifer is identical. The quartz dissolves to saturation. Its solubility is unaffected by the addition of the CO_2 (Figure 11.5.4). No new phases are formed and the amounts of calcite and dolomite dissolved are identical.

In the case of a calcium-rich brine (see Figure 11.5.5), the same conclusions hold except the amount of CO_2 and calcite dissolved is less. Consequently, depending upon the specific formation water chemistry, reaction of a carbonate formation can result in an increase of dissolved carbon dioxide by 1 to 4 percent.

The formation waters in carbonate aquifers may be dilute or concentrated, but generally they are dominated by sodium and chloride. The calcium and magnesium concentrations can be quite low (particularly if the pH of the formation water is basic) as they are controlled by the solubility of the carbonate minerals. Dissolution of calcite or dolomite will increase the calcium and magnesium concentration in the water. This increase will be offset by the buffering effect provided by the cation exchange equilibria with the clays. This effect is most pronounced for low ionic strength formation waters.

Clays have a large exchange capacity and can have an important effect on water composition. The cation exchange capacity (i.e. CEC) are largest for the smectite group, which have a range of 100 to 140 milli-equivalents per 100 grams of smectite. The average CEC's for illites is 20 to 40 milli-equivalents per 100 grams and for kaolinites is 10 milliequivalents per 100 grams. For a rock containing 10% clay which is composed of equal amounts of smectite and illite, the CEC would be approximately 6 to 9 meq per 100 grams of rock. If the carbonate formation contains 5 wt% clay (1000 grams of clay per litre of water) which is comprised of equal amounts of illite and smectite, then the CEC would be 800 meq per litre of water. In this formation, a calcite-saturated brine passing over a Na-exchanged clay, would exchange Ca for Na by a reaction similar to:

$$2\text{Na-clay} + \text{Ca}^{++} = \text{Ca-clay} + 2\text{Na}^{+}$$

TABLE 5.2a STARTING MINERALOGY FOR PATH.UBC MODEL RUNS

Run =	Dilute	Brine	Cc Dol	Cc Dol	CC Dol	Cc Dol	Cc Dol	Anorth	Anorth	Anorth	Anorth	Anorth	Chlorite	Albite	Kspar	Amount
Brackish	✓		✓	✓		✓		✓					✓	✓	✓	
Brine		✓			✓		✓		✓	✓	✓	✓				
Calcite			100/ Equil	100/ Equil	1/ Equil	100/ Equi	1/ Equil			1/ Equil						grams rate
Dolomite			100/ Equil	100/ Equil	1/ Equil	100/ Equi	1/ Equil			1/ Equil	1/ Equil	1/ Equil				grams rate
Na_2X						1/ Equil	1/ Equil									moles rate
Quartz				100/ Equil				1000/ Equil	1000/ Equil	1000/ Equil	50/ Equil	50/ Equil	1000/ Equil	1000/ Equil	1000/ Equil	grams rate
Anorthite								1000/ 100	1000/ 100	1000/ 100	1000/ 1	90/ 1				grams rate
Ca Smectite											1000/ 1	110/ 1				grams rate
Kspar															1000/ Equil	grams rate
Illite/ Muscovite								1000 Equil			500/ Equil	5/ Equil		1000/ Equil	1000/ Equil	grams rate
Albite														1000/ 1000		grams rate
Clinochlore													1000/ 1000			grams rate

TABLE 5.2B WATER CHEMISTRY FOR PATH.UBC MODEL RUNS

Run =	Dilute	Brine	Cc Dol	Cc Dol	CC Dol	Cc Dol	Cc Dol	Anorth	Anorth	Anorth	Anorth	Anorth	Chlorite	Albite	Kspar	Composition
IS	0.063/	4.00/	0.063/	0.063/	6.57/	0.069/	6.59/	0.063/	3.74/	4.19/	3.47/	3.47/	0.063/	0.063/	0.063/	Start
	0.068	4.12	0.248	0.248	6.74	0.295	6.77	0.263	4.03	4.75	4.16	3.32	0.24	4.41	0.74	End
Na	1420/	746/	1420/	1420/	285/	1405/	27938/	1420/	37904/	38197/	29640/	29640/	1420/	1420/	1421/	ppm, Start
	1207	70362	1208	1208	27266	4024	26777	1324	40549	45275	33780	28196	1270	68977	1237	ppm, End
K	0.0/	0.0/	0.0/	0.0/	0.0/	0.0/	0.0/	13/	1052/	3/	954*/	954*/	0.0/	13/	28/	ppm, Start
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.44	1892	3	6234	1579	0.0	35	20266	ppm, End
Mg	0.2/	0.3/	0.3/	0.3/	1779/	0.3/	1763/	0.3/	3594/	398/	3461*/	3461/*	0.3/	0.3/	0.3/	ppm, Start
	0.2	0.3	83.	83.	1713	30	1701	0.0	590	379	718	622	1333	0.1	0.2	ppm, End
Ca	5.5/	9.4/	5.5/	5.5/	49358/	5.6/	48911/	5.5/	13667/	23447/	16608/*	16608/*	3.5/	5.5/	5.5/	ppm, Start
	4.8	8.9	*1772	1772	47613	642	47271	1253	15826	22576	19333	16452	0.0	1.3	4.5	ppm, End
pH	8.23/	8.23/	8.23/	8.23/	5.60/	8.23/	5.60/	8.23/	4.60/	5.60/	6.70/	6.70/	8.23/	8.23/	8.23/	ppm, Start
	3.55	3.67	4.68	4.68	4.01	4.90	4.01	4.75	4.29	4.01	4.24	4.28	5.16	6.29	5.37	ppm, End
Cl	1868/	114645/	1868/	1868/	136322/	1439/	134742/	1880/	93789/	102529/	85565/	85565/	1867/	1880/	1895/	ppm, Start
	1588	108250	1587	1588	130793	1224	129408	1824	92754	111911	92613	74081	1648	1402	1580	ppm, End
SO_4	0.0/	0.0/	0.0/	0.0/	0.0/	0.0/	0.0/	0.0/	0.0/	0.0/	649*	649*	0.0/	0.0/	0.0/	ppm, Start
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	456	576	0.0	0.0	0.0	ppm, End
HCO_3	555/	455/	555/	555/	24/	548/	24/	555/	481/	8.5/	4.5/	4.5/	555/	555/	555/	ppm, Start
	500	479	6289	6287	839	10507	819	7536	2096	281	1872	2285	7229	180547	32207	ppm, End
CO_2	$9.3x10^{-5}$	$4.1x10^{-5}$	$9.3x10^{-5}$	$9.3x10^{-5}$	$8.5x10^{-4}$	$9.3x10^{-5}$	$8.5x10^{-4}$	$9.3x10^{-5}$	0.185	$4.7x10^{-4}$	$1.4x10^{-5}$	$1.4x10^{-5}$	$9.3x10^{-5}$	$9.3x10^{-5}$	$9.3x10^{-5}$	molality,Start
	4.32	1.71	4.13	4.13	1.22	4.04	1.21	4.11	1.78	0.64	1.74	2.05	1.33	1.64	3.62	molality, End
H_2O	51.49	53.85	51.61	51.61	54.30	51.65	54.31	44.84	47.12	47.77	43.12	52.61	57.66	50.79	51.52	molality, End
a CO_2	4.41	3.98	4.41	4.41	4.01	4.36	3.98	4.39	4.08	1.45	4.10	4.18	1.41	4.01	4.34	activity, End
Cc	0/	0/	-0.05/	-0.05/	-0.0081/	-0.09/	-0.0081/	3.56/	3.31/	3.59/	3.83/	0.10/	0/	0/	0/	moles ppt., End
Dol	0	0	-0.004	-0.004	-0.00035	-0.006	-0.0035	0.00	0.14	0.06	0.14	0.14	8.9**	0	0	moles ppt., End

* SO_4 complexes not included ** refers to magnesite

Figure 5.1

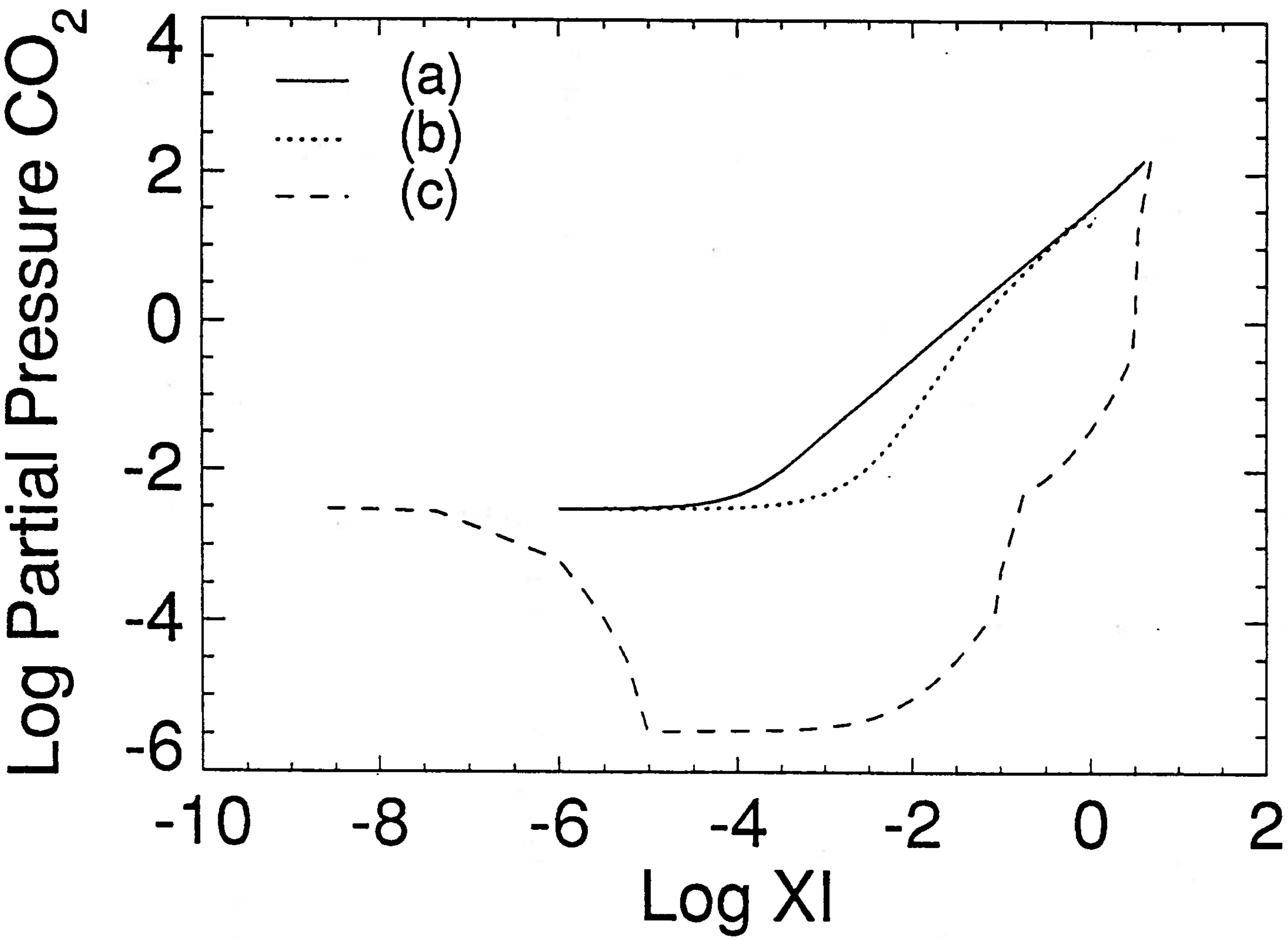


Fig. 5.1: Buildup of the partial pressure of CO_2 in bars as a function of time ('XI'): (a) in brackish formation water; (b) in brackish formation water in a calcite-dolomite aquifer with ion exchange; (c) in brackish formation water in an albitic (i.e. Na-rich) siliciclastic aquifer.

Figure 5.2

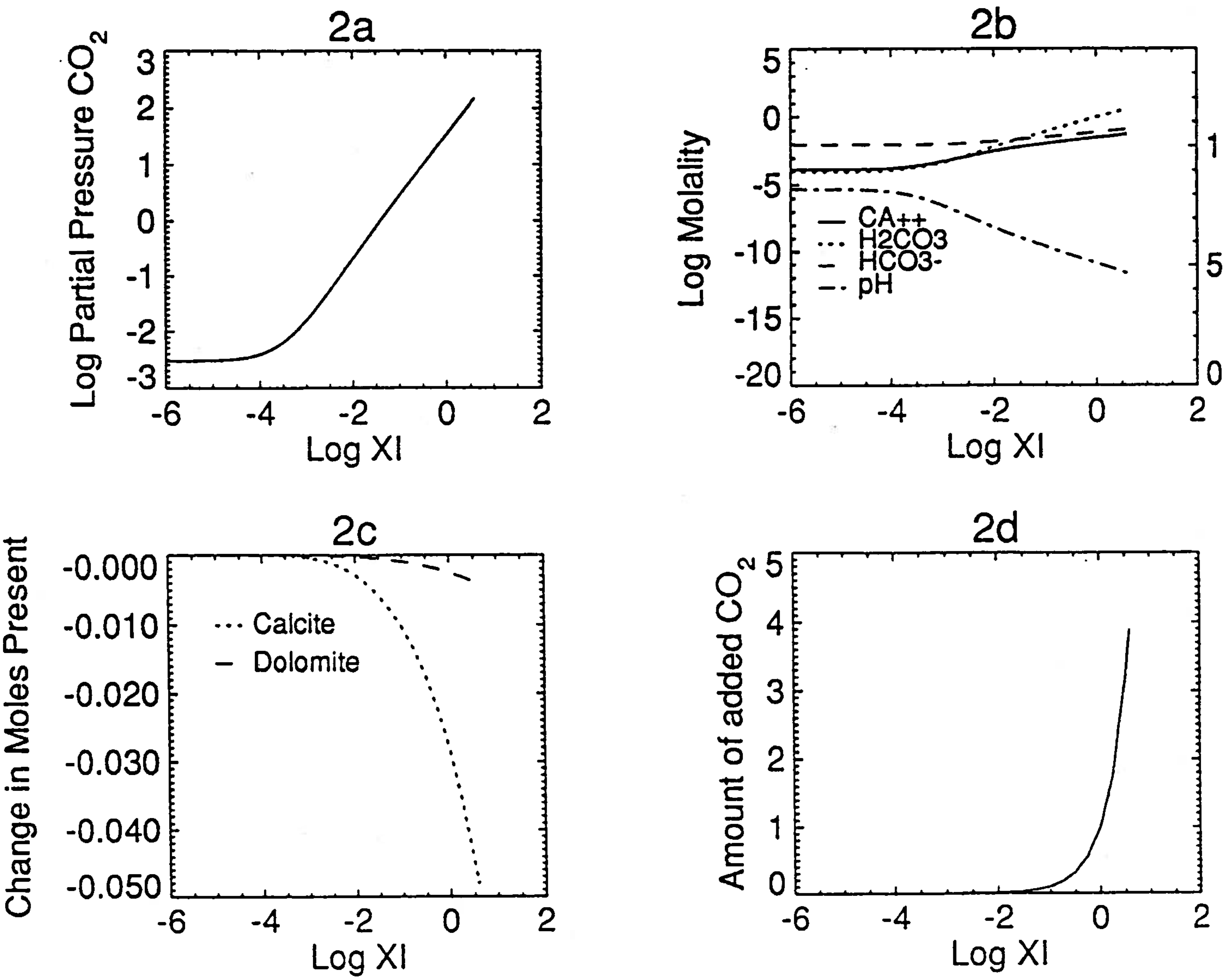


Fig. 5.2: Reaction of brackish formation water with a calcite-dolomite carbonate aquifer as CO_2 is injected into the aquifer; plotted as a function of time ('XI'): (a) buildup of the partial pressure of CO_2 in bars; (b) change in the molality of the aqueous species; (c) change in the moles of mineral reactants; (d) molar amount of CO_2 injected into the aquifer.

thus decreasing the amount of calcium in the formation water. Consequently, the amount of carbon dioxide dissolved in the formation water due to carbonate mineral dissolution could be substantially increased because the calcium concentration is buffered through absorption onto exposed clay surfaces. This may occur as a marly section of the carbonate aquifer is broached and new formation fluids pass through it.

To quantify this effect, modelling of formation waters, equilibrated with a carbonate aquifer at 15 MPa CO_2 pressure, was completed as discussed above. The computer code, SOLMINEQ.88 (Kharaka et al., 1988), was used for the modelling. Initially, the composition of the clay exchanger was calculated based upon equilibrium with the formation waters before any CO_2 is added. Then the formation water was equilibrated with 15 MPa CO_2 in the absence of exchanger. Finally the formation water was re-equilibrated with clay exchanger at 15 MPa CO_2. For the dilute formation water, the calcium concentration changed from 5 to 1772 mg/L as the CO_2 was added while maintaining calcite saturation. The calcium level dropped to 158 mg/L once the exchanger was equilibrated at the 15 MPa CO_2 pressure and calcite became undersaturated by an order of magnitude.

Figure 11.5.6 documents the reaction path for a similar case calculated using PATH.ubc. This calculation maintains equilibrium between exchange sites on the surface of the clay, calcite, dolomite and solution at all times during CO_2 addition. The increase of calcium and magnesium on the exchanger is clearly seen as the calcite and dolomite dissolve into the aqueous phase. When equilibrium between the exchanger, the carbonate minerals and formation water is satisfied at 15 MPa of CO_2 pressure, the amount of excess CO_2 dissolved in the formation water attributed to the combined effects of ion exchange and carbonate mineral dissolution is doubled. This is shown by the depression of the CO_2-'XI' curve (curve b, Figure 5.1) For a calcium-rich brine, no increased dissolution of the carbonate minerals was observed (Figure 11.5.7) compared to the same reaction in the absence of exchange sites on clay surface. Thus no excess capacity for CO_2 is generated by the presence of clay exchange sites in a calcium-rich brine.

5.6 CO_2 SOLUBILITY IN SILICICLASTIC AQUIFERS

Siliciclastic aquifers containing basic silicate minerals, can absorb more CO_2 (see Gunter and Bird, 1988, for an explanation) than other aquifers through a complex set of water-rock reactions. These reactions can be summarized in a general sense by the reaction of feldspar and clay silicate minerals with CO_2:

$$\text{Feldspars} + \text{Clays} + CO_2 \rightarrow \text{Kaolinite} + \text{Calcite} + \text{Dolomite} + \text{Quartz}$$

The reactant clays comprise of both illites and smectites. The final ratio and the respective amounts of the calcite to dolomite depend on the initial formation mineralogy and formation water composition. The more feldspars and clays initially present, the more carbonate minerals produced as reaction products and the more carbon dioxide trapped in the formation.

Aquifers meeting these qualifications can be divided into two types: those in which the dominant basic silicate minerals are calcium and magnesium-rich and those in which they are sodium and potassium-rich. The first will absorb the most CO_2 because the silicate breakdown will release calcium and magnesium which combine with the injected CO_2 to form calcite and dolomite. The absorption of CO_2 for the second type is less. The breakdown of the basic silicates neutralizes the dissolving CO_2 and forms bicarbonate ions in the fluid. The potassium and sodium concentrations (released when the basic silicates breakdown) build up in solution, because the solubilities of potassium and sodium carbonates are much higher than those of calcite and dolomite. Consequently the ionic strength of the brine will build up until the partial pressure of CO_2 in the fluid is 15 MPa and the fluid is in equilibrium with the formation minerals that remain. It is appealing to speculate that a set of conditions exist under which saturation with one of the alkali carbonates is reached, similar to the formation of the sodium carbonate-rich lakes at the earth's surface. These conditions have not been identified for CO_2 injection into Alberta aquifers.

The reaction paths followed by the formation fluid when CO_2 is injected into a siliciclastic reservoir can be followed on phase diagrams; diagrams which plot the relative stability fields of minerals as functions of the activities or activity ratios of various species in the formation fluid. Figures 11.5.8a, b, c, d represent the systems K^+/H^+ versus H_4SiO_4, Na^+/H^+ vs H_4SiO_4, $Ca^{++}/(H^+)^2$ vs H_4SiO_4 and $Mg^{++}/(H^+)^2$ versus H_4SiO_4, respectively, and were calculated using the geochemical computer program, GeoCalc. The basic silicate mineral stability fields occupy the areas of these phase diagrams where the cation over hydrogen ion ratio is high. On the first three figures, this area is represented by a feldspar mineral (potassium feldspar, albite or anorthite) or zeolite (anorthite would occupy the laumontite field); on the fourth, this area is represented by the chlorite mineral, clinochlore. All of these diagrams were calculated assuming that all minerals were in equilibrium with water.

The diagrams do not take into account the effects of solid solution on the size of each of the mineral stability fields, even though the end-member feldspars, zeolites and clays generally do form solid solutions with the other end members in the same mineral group. The reason for this assumption is simplicity; the thermodynamic data for solid solution minerals is non-existent or poor, and the numerical methods for calculating dynamic equilibrium for solid solution minerals are intractable.

Generally, we have chosen to take a simple approach to modelling the effect of the four end member basic silicates on CO_2 uptake. We have represented the aquifer solids as a three phase mixture; excess quartz (representing the dominant phase in the aquifer solids) and 1000 grams (i.e. 5 wt%) of each of the basic end member silicate and clay mineral illite (note that we used muscovite as a proxy for illite in the modelling).

To model the effects of CO_2 addition to a formation mineralogy rich in calcium, the three-phase assemblage, anorthite, muscovite and quartz, in dilute or brackish formation water was allowed to react with CO_2 (Table 5.2). The calculated reaction paths are complex with anorthite and quartz initially reacting to form laumontite (Figures 5.3c, d (or Figure 11.5.9b). Illite is stable and little reaction occurs. Once all the anorthite has reacted, the laumontite then breaks down to form kaolinite, calcite and quartz. The reaction progress can be followed by monitoring the change in the aquifer water chemistry (Figure 5.3b) or the partial pressure of CO_2 in Figure 5.3a (or Figure 11.5.9a). The first part of the curve is similar to that for no water-rock reaction; flat. However instead of a steep rise, the CO_2 sharply drops to a flat minimum as first the pH is buffered to more basic conditions and then as calcite precipitates. Each plateau in the minimum of the CO_2 curve marks the loss or precipitation of a new phase. The CO_2 pressure starts to rise sharply to the final imposed pressure only after all the laumontite has reacted. There is no source of calcium left to form calcite, thus allowing the level of carbonate (dissolved CO_2) in solution to increase rapidly. In addition, a small amount of calcite will dissolve as the CO_2 pressure builds up to 15 MPa (Figure 5.3d). Approximately four moles of CO_2 have precipitated as calcite. The amount of CO_2 locked up in the aquifer has doubled when compared to the non-reactive or to the carbonate aquifer cases. If the mass of available anorthite had been increased, more CO_2 could have been trapped by the continued precipitation of calcite.

The reactions between a formation brine, an anorthite-rich formation, and injected CO_2 are different from the brackish formation water case because of the more concentrated constituents of the brine. For this modelling run, only quartz and anorthite were used to represent the formation mineralogy as illite was essentially inert (Table 5.2). The initial pressure of CO_2 in the brine is much higher because of the different formation fluid composition but the shape of the pressure curve (Figure 11.5.10a) is similar; it has a deep minimum followed by a vertical rise to the final CO_2 pressure of 15 Mpa. The observed reactions are different because of the higher sodium concentrations and buffering effects of the brine. Na-smectite is stabilized over laumontite. Prehnite forms as an intermediate calcium phase. Both the prehnite and Na-smectite break down to form calcite and kaolinite. The final equilibrium mineral assemblage (calcite, quartz and kaolinite)is similar to the dilute formation water case; only the intermediate steps of the reaction path are different. The total amount (approximately 4 moles) of calcite formed is similar to the brackish formation water case, but the total CO_2 consumed is less; only approximately 5 moles. This is largely due to the limited solubility of CO_2 in brines; the salting out effect.

The effect of temperature on CO_2 injection into a calcium-dominate basic formation mineralogy was investigated at 100°C. As shown by Figure 11.5.11, similar reactions occur. Anorthite is replaced by prehnite which in turn breaks down to kaolinite. Sodium smectite also appears briefly. Although the solubilities of these minerals change significantly with the higher temperature, the same reaction drive dominates; the conversion of basic aluminous silicate minerals to kaolinite by acidic CO_2. The resulting reaction path is very similar to the 25°C case. Approximately 4 moles of calcite is precipitated. The total mass of CO_2 consumed is less than the 25°C case because the solubility of CO_2 in a brine is lower at higher temperatures.

If CO_2 reacting with a brine and a more complex calcium mineral assemblage involving intermediate and basic minerals is modeled at 25°C, the reaction path will be considerably more complex but the final results will be similar to the previous cases. For example, by adding 1000 grams of Ca-smectite to the anorthite-muscovite-quartz assemblage, the shape of the CO_2 pressure curve (Figure 11.5.12a) changes slightly. The first part of the curve is similar; flat. Then the pressure starts to rise and then drops as the silicate-water reactions start to dominate. Both anorthite and Ca-smectite break down to form sodium smectite, calcite and kaolinite. Trace amounts of dolomite and anhydrite are also made. Illite is essentially inert. In the final stages of the reaction, Na-smectite also breaks down to form kaolinite. Four moles of calcite are formed, similar to the two cases above. Only 6 moles of CO_2 were consumed due to the salting out effect.

If the amounts of the accessory minerals are decreased by an order of magnitude (i.e. to 100 grams of anorthite and smectite), the shape of the CO_2 pressure curve is similar (Figure 11.5.13a) to the previous calculations. The minimum is not as deep nor as wide because there are fewer basic silicate minerals (anorthite) available for reactions. However, the observed reactions are very similar to the previous calculations. At equilibrium, 0.2 moles of calcite has been made; and the brine formation water, not the solids, has trapped the majority of the CO_2. This emphasizes the earlier results **that the actual amount of CO_2 locked up by precipitation of carbonate minerals is limited only by the amount of basic calcium silicate mineral present in the aquifer solid assemblage**. Once again, the salting out effect has limited the solubility of CO_2 to two moles in the brine instead of the four dissolved in brackish water. We expect the major effect of the brine will be the same in all other cases. Therefore, the modelling of magnesium, sodium and potassium silicate systems will be continued only using the dilute formation water.

The magnesium-rich siliciclastic aquifers behave similarly to the calcium-rich ones. In Figure 11.5.14, the reaction path for 5 wt % clinochlore with excess quartz is shown. The pressure of CO_2 remains low until the end where it rises almost vertically. The initial magnesium formation mineral, clinochlore, reacts to form talc and kaolinite. Once clinochlore has reacted out, the talc in turn breaks down to form magnesite, the magnesium analogue to calcite. The final assemblage is quartz, magnesite and kaolinite. Over 9 moles of magnesite had formed, at which time the model became unstable. The final CO_2 pressure reached was only 5 MPa with only 1.4 moles of CO_2 dissolved in the water. The magnesium reactions appear more promising as a CO_2 sink than their calcium counterparts.

Figure 5-3

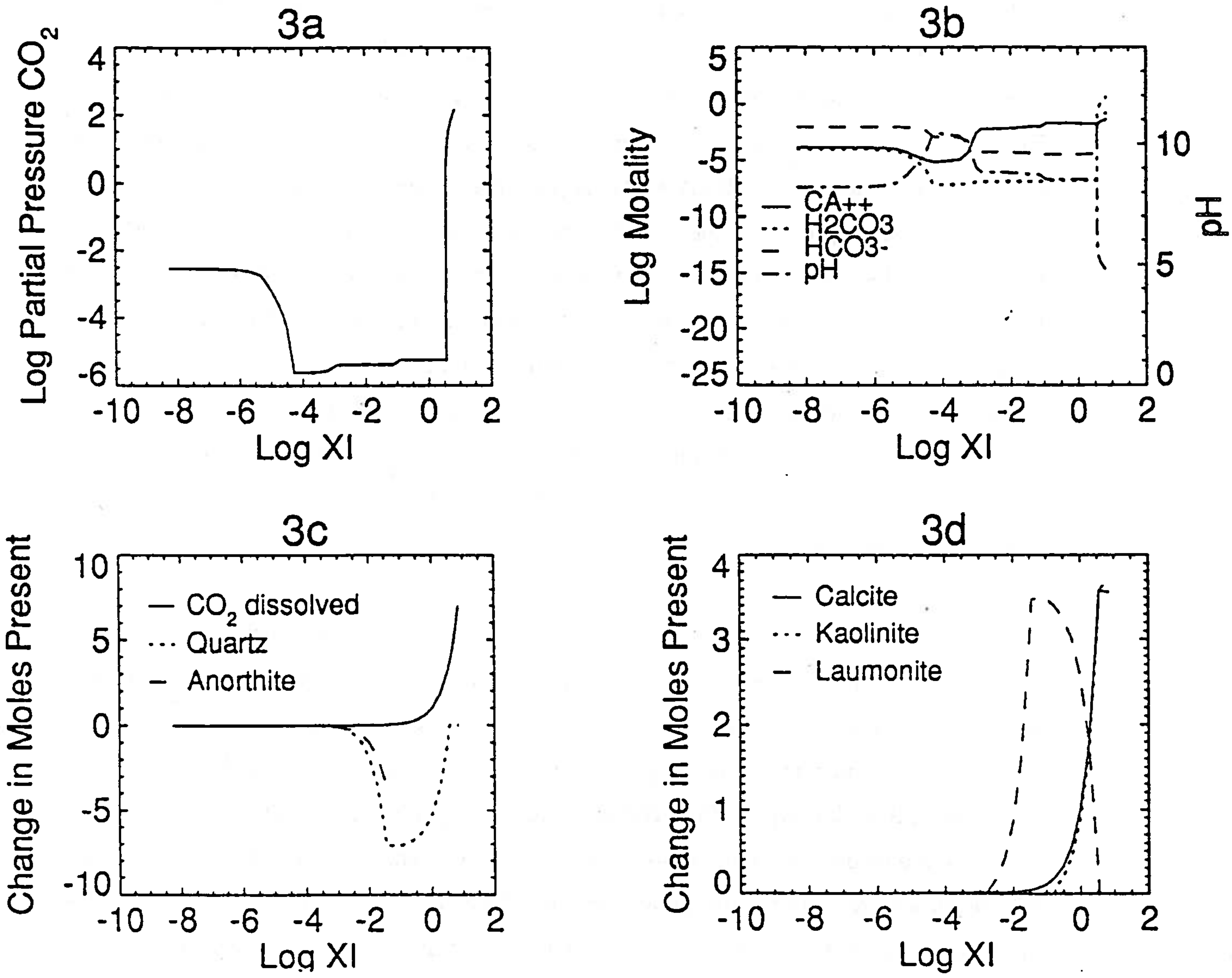


Fig. 5.3: Reaction of brackish formation water with an anorthite- muscovite-quartz siliciclastic aquifer as CO_2 is injected into the aquifer; plotted as a function of time ('XI'): (a) buildup of the partial pressure of CO_2 in bars; (b) change in the molality of the aqueous species; (c) change in the moles of the initial formation mineralogy and the amount of CO_2 injected into the aquifer; (d) change in the moles of mineral products.

The sodium-rich siliciclastic aquifers were modelled as a mixture of 5 wt% of albite and illite in the presence of excess quartz. As was observed in previous simulations, the illite behaved inertly. The albite reacts to form jadeite which in turn breaks down to form sodium smectite. The final equilibrium assemblage is illite, quartz and sodium smectite. The kaolinite stability field was never reached because the large sodium build up in the formation fluid stabilized smectite. The CO_2 pressure curve (Figure 5.1, Curve "c" (or Figure 11.5.15a)) rises from the minimum much earlier than for the Ca- or Mg- cases (Figure 5.3a) because no carbonate phases precipitate. Final CO_2 take-up is 5 moles, of which 4.4 moles is present in the form of bicarbonate ion and 1.6 moles as dissolved CO_2. Even though the initial formation water was a brackish formation water (Table 5.2), the build-up of the bicarbonate ion increases the ionic strength from 0.063 to 4.41. This results in a significant salting out effect for the dissolved CO_2. The observed concentration of bicarbonate is more than an order of magnitude higher than calculated for the calcium- or magnesium-rich siliciclastic aquifers. As discussed earlier, the build-up of bicarbonate cannot occur for the calcium or magnesium cases because of early saturation with calcite, magnesite and/or dolomite.

The effects of CO_2 addition to a dilute formation water in a potassium-rich siliciclastic reservoir were modelled using a formation composed of 5 wt% of each potassium feldspar and illite, in the presence of excess quartz. Under these conditions, the potassium feldspar reacted to form muscovite and quartz, both of which remained in equilibrium with the fluid during the addition of CO_2. The pressure of CO_2 climbed steadily (Figure 11.5.16a) similar to the carbonate aquifer case (Figure 5.1, curve b) and was not affected significantly by the mineral reactions. The potassium subsystem is by far the least reactive of all the siliciclastic systems considered under high CO_2 pressures; the final bicarbonate ion concentration reaches only 0.6 molal. Although this is considerably higher than its calcium and magnesium counterparts, it is only a fraction of the concentrations reached by the sodium analogue case. Consequently, siliciclastic aquifers dominated by potassium accessory phases would not enhance the CO_2 uptake significantly above the 4 moles dissolved in the inert (mineral absent) aquifer case.

6.0 VALIDATION OF GEOCHEMICAL MODELLING

6.1 EXPERIMENTAL DESIGN

Autoclave experiments were designed to confirm the results of these geochemical modelling predictions. A synthetic brackish formation water was prepared according to the following recipe: 0.05261 M sodium chloride, 0.000335 M potassium chloride, 0.000138 M calcium chloride, 0.0000116 M magnesium chloride, 0.009134 M sodium bicarbonate and 0.000139 M sodium carbonate. Drill core from a siliciclastic aquifer (6-18-50-3W5, 1555.65m) was ground to a fine powder. Relatively pure mineral specimens from Ward's Natural Science Ltd. were also ground to a fine powder. The powdered drill core and mineral powders were characterized by XRD and SEM. Mixtures of 10 grams of the powdered drill core with:

a) 30 grams of powdered albite (Na-feldspar); experiment 411,
b) 20 grams of powdered clinochlore (Mg-chlorite); experiment 414,
c) 30 grams of powdered microcline (K-feldspar); experiment 410,
d) 30 grams of powdered labradorite (Ca-feldspar); experiment 412, and
e) a control, the siliciclastic aquifer by itself; experiment 437

are placed into 300 ml autoclaves and sealed. Each autoclave had two ports in the head at the top to facilitate aqueous sampling. One port was affixed with a dip tube which extended to within 1.5 cm of the bottom of the autoclave, and the other with a 2 cm diameter sintered stainless steel filter, with a nominal pore size of 0.5 microns. Approximately 1.2 moles (53 g) of carbon dioxide were transferred into each sealed autoclave quantitatively. Finally the autoclaves were filled with approximately 250 grams of the simulated brackish formation water. This was done by connecting them to a piston type hydraulic accumulator containing the water on one side of the piston, and nitrogen at approximately 88 bars on the other. The autoclaves were thereby pressurized hydrostatically to about 88 bars. The pressure was monitored by means of a pressure transducer fixed on each autoclave. The autoclaves were weighed to ensure no loss of the contents. They were placed in an enclosure at room temperature (20°C). The contents of the autoclaves were constantly stirred by means of magnetic stir bars. Pressure in the autoclaves cycled with room temperature by plus or minus about 8 bars.

The autoclave contents were allowed to react for approximately four weeks. During this time, the pressures were constantly monitored. They were weighed at regular intervals to confirm no loss of the contents, and checked to ensure that stirring of the contents was maintained.

At the end of this time, the aqueous contents were sampled. A sample tube was pressurized to 88 bars (autoclave pressure) with nitrogen and connected at the top of the autoclave to the port with the filter element. At the outlet end of the sample tube, a back pressure regulator (BPR) was connected and set to maintain an 88 bar pressure. A heavy immiscible liquid (dichloro methane) was injected at 88 bars through the dip tube into the bottom of the autoclave, displacing the aqueous sample into the sample tube. At the same time, the nitrogen was displaced from the sample tube through the BPR to the atmosphere. After the contents of the sample tube were flushed about three times, the sample tube was isolated by closing values at either end. Injection of the dichloro methane continued through a by-pass line, along side the sample tube, and through the BPR. This was done until all of the water and carbon dioxide were displaced from the autoclave. The replacement of the water, under pressure, ensured that no minerals precipitated as a result of the de-gassing that occurs as a result of depressurization at the end of the experiment.

The CO_2 was collected quantitatively from the sample tube by slowly depressurizing into a Brooks Gas Meter. The remaining aqueous sample was analyzed for cations by ICP, and alkalinity, chloride and sulphate by IC. The autoclave, with dichloro methane at 88 bars, was depressurized and opened. The powder was removed, dried, and analyzed by XRD and SEM to determine the extent of reaction.

6.2 PRODUCT EXAMINATION

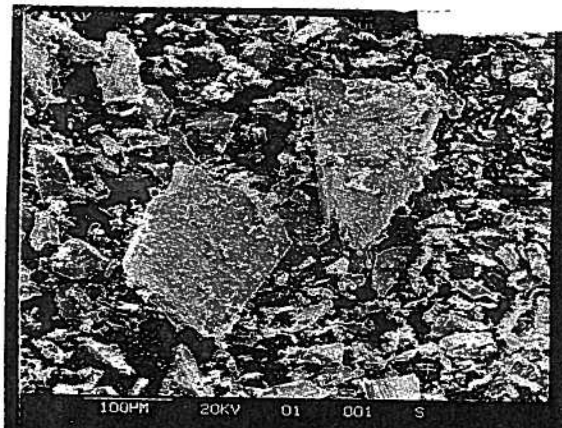
The X-Ray charts for each of the autoclave experiments are shown in appendix 11.6.2. Three charts are presented for each experiment, the first shows the entire X-Ray scan, while the second and third charge provide the 2-Theta measurement and D-spacings for each peak in the range of 2 to 34 degrees 2-Theta and 34 to 66 degrees 2-Theta, respectively.

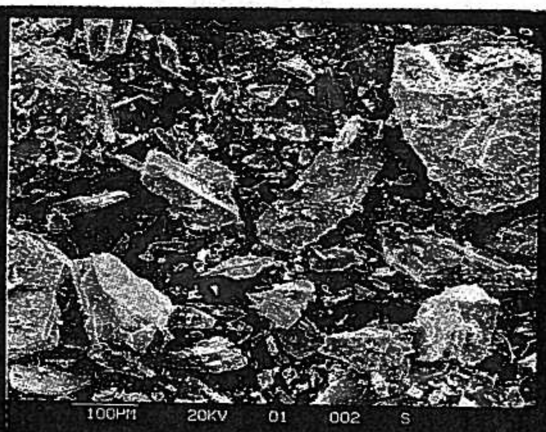
The observed changes to the mineralogy in the autoclaves, as determined by X-Ray diffraction, are small. The largest change was less than 5 weight percent of the sample. A new phase (peak at 4.91 angstroms) formed in Run 437 (the control) but could not be identified as only one x-ray peak was clear. Approximately 2-3% of illite was formed in Run 410 (microcline addition to the control). The presence of illite is consistent with the modelling, which used muscovite as a proxy for illite. Two new peaks have been observed in Run 411 (albite addition to the control), one tentatively can be identified as kaolinite while the other is probably an amphibole. An approximate total of 3 weight percent (of both) were formed. Two new peaks were observed in Run 412 (labradorite added to the control), one is kaolinite while the other could not be identified. The masses of the two total to approximately 3%. The formation of kaolinite is consistent with calcium siliciclastic modelling runs. No new peaks, hence no new phases, were observed in Run 414. The presence of new carbonate minerals could not be identified in any of the charts. As some carbonate phases were present in the siliciclastic control, thus in all on the experiments, small changes in the weight percent present would not be possible to observe.

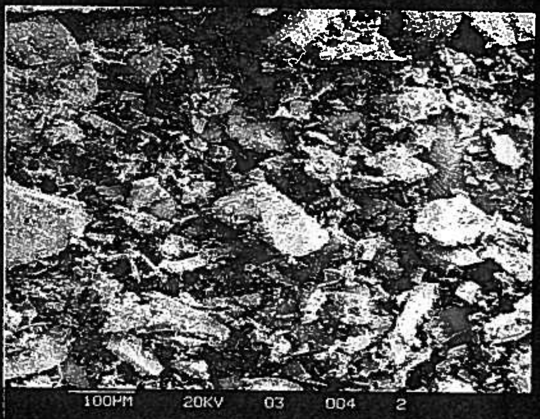
Figures 6.1A and 6.1B contain SEM photographs of the pre- and post run solids from the autoclave experiments. The magnification of the photos is 120 times. Each photo is identified by the fourth number at the base of the photo. Photos one through seven examine the pre-run samples (photos #1 & #2 are from Run 411; #3 is from Run 412; #4 is from Run 410; #5 from Run 414; #6 and #7 are from Run 437). Of interest is the calcite rhomb visible in photo 7. All of the mineral grains have sharp angular edges and cleavage is visible on some of the larger grains. Photos eight through thirteen examine the run products (photo #8 is from Run 411; #9 & #10 are from Run 414; #11 is from run 410; #12 is from Run 412; #13 is from Run 437). No new minerals could be identified in any of the photos, however, evidence of quartz overgrowths can be clearly seen in photos #8, #9, #10, #11 and #13. For example on photo 13, the largest grain in the lower left corner is quartz and can be seen to have clearly defined crystal terminations. Quartz overgrowths were also identified in the post-run products from autoclave run 412 but can not been seen in photo #12. In every geochemical modelling simulation where silicate minerals were present, quartz was formed as a product mineral, even when it initially dissolved. Thus the presence of quartz overgrowths is consistent with the geochemical modelling.

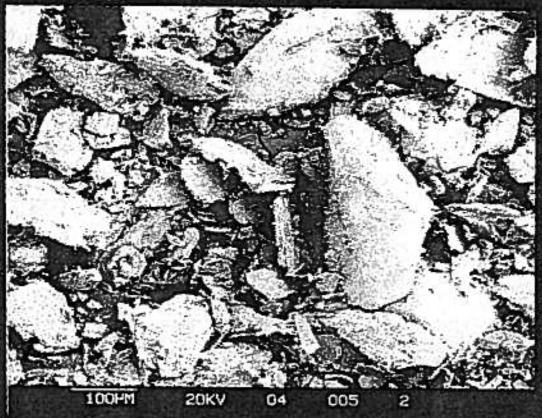
Table 6.1 contains the analytical results for the composition of the initial water and for each of the waters in the autoclaves at the end of the experiments.

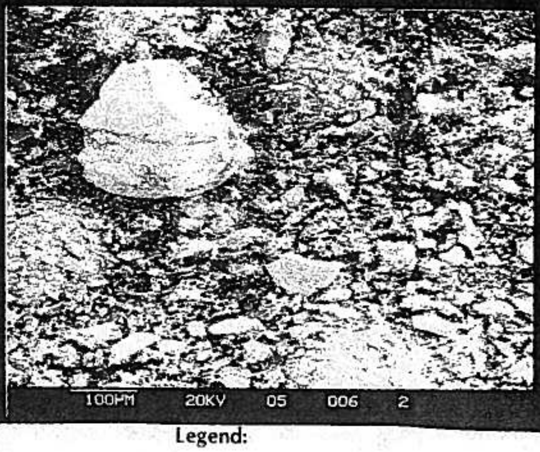
pH decreased in all the experiments, but most significantly for the control. pH is expected to decrease with increasing amounts of dissolved carbon dioxide, however it will be buffered by reactions with the silicate mineralogy (see discussion in the modelling section). The greater reactivity of the "spiked" samples (autoclave runs #410, #411, #412 and #414) has resulted in increased amounts of silicate mineral buffering, thus the pH has not shifted as much.

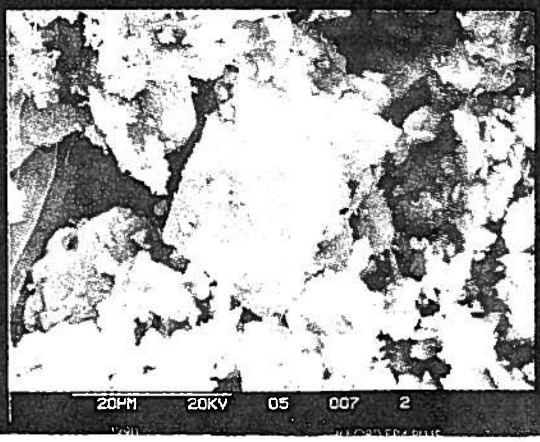








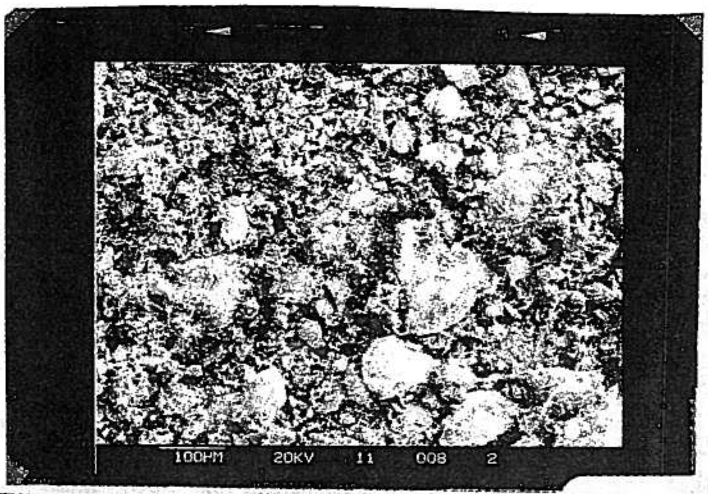


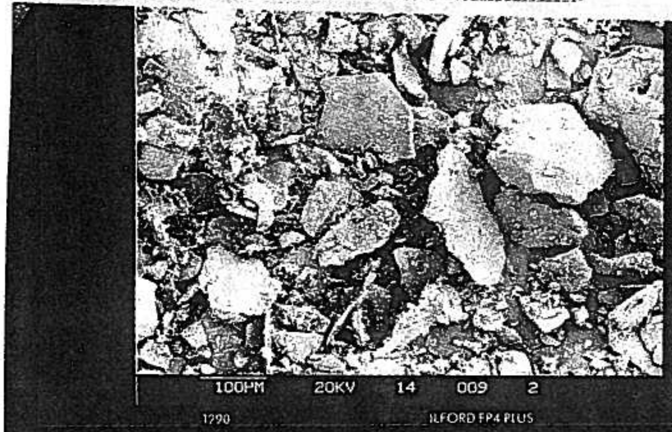


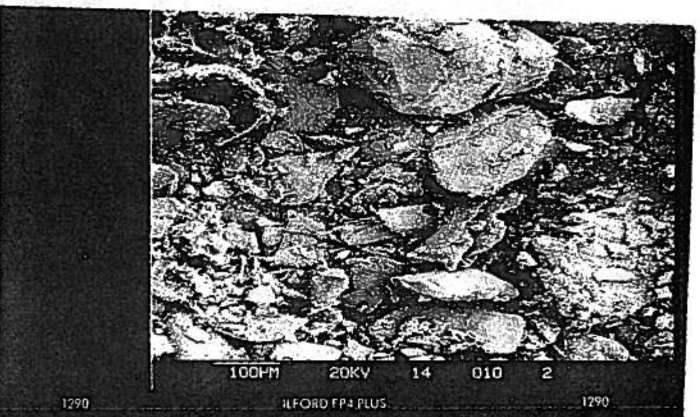
Legend:

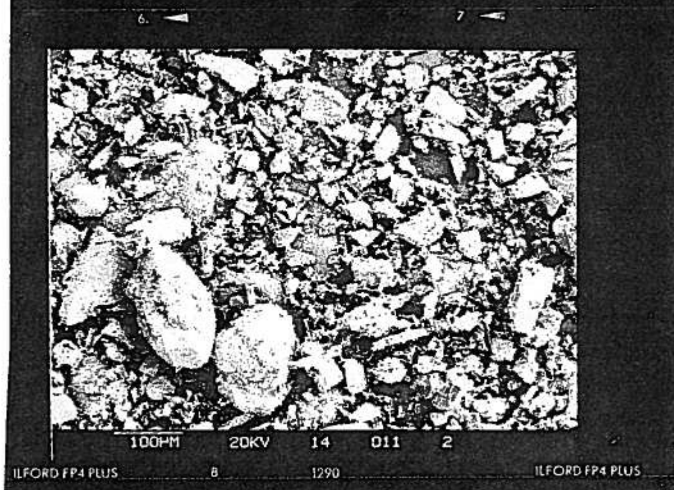
001/002 - Run 411
003 - Run 412
004 - Run 410
005 - Run 414
006/007 - Run 437

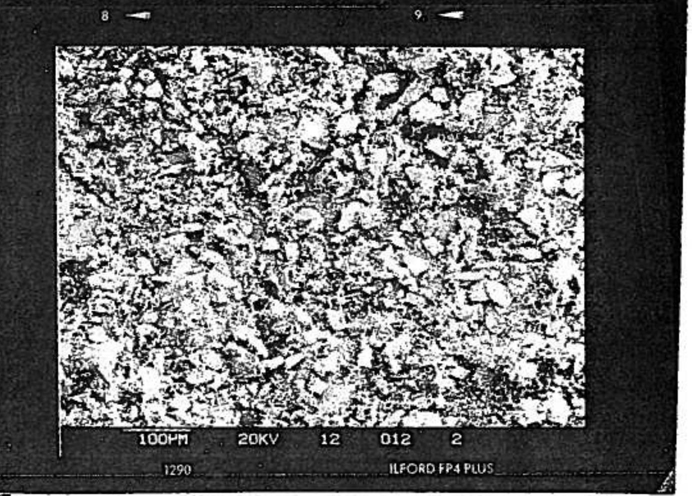
PRE-RUN SAMPLES
FIGURE 6-1A

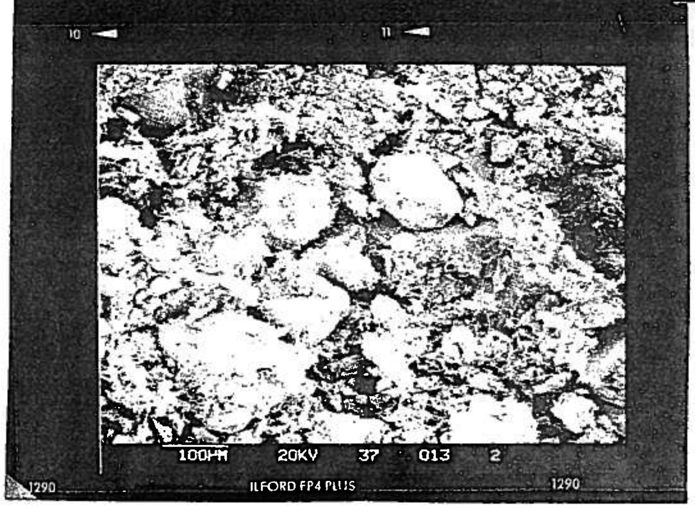












Legend:

008	-	Run 411
009/010	-	Run 414
011	-	Run 410
012	-	Run 412
013	-	Run 437

POST-RUN PRODUCTS
FIGURE 6-1B

The alkalinity has increased for all of the runs, but most for the spiked runs because the silicate minerals buffered the pH. As discussed previously, this buffering allows the dissolution of slightly more carbon dioxide. The observed alkalinity values correspond to approximately 0.08 moles of total dissolved carbon dioxide, indicating that the experiments are still far from final equilibrium values.

The sodium levels vary around the initial pre-run value. Because of the relatively high concentration of sodium in the charge, these variations can not be assigned to a reaction and are probably the result of normal analytical error.

The calcium levels have increased in all of the runs. Only 0.3 grams of calcite would have to be present in the siliciclastic formation mineralogy and dissolve completely to raise the solution composition to the observed calcium levels of approximately 500 mg/l. Experiment #412 was spiked with Labradorite, a calcium-sodium feldspar, thus higher levels of calcium would be expected. This was not observed, thus precipitation of the calcium derived from the labradorite in another phase must have occurred. The X-ray charts contained evidence of a phase which could not be identified. Based upon the modelling and mass balances, it is probably that it was either a calcium zeolite or a calcium smectite.

Potassium levels increased slightly for all runs, except for the experiment spiked with Microcline (Run 410) which had it's potassium levels increased by over 3 times compared to the other experiments. Microcline contains potassium, thus a larger increase would be expected unless the formation of illite buffers the potassium level. Illite was identified as a reaction product in both the modelling and the X-ray examinations. It's formation buffered the potassium levels to the observed levels.

Table 6-1

Aquifer Disposal of Carbon Dioxide Autoclave Experiments						
Analysis of Post Run Waters						
Concentration	Pre-Run	410	411	412	414	437
mg/l						
Alkalinity (HCO3)	570	3360	3420	4180	3600	1520
pH	7.25	6.49	6.48	6.56	6.49	6.16
Chloride	1820	1480	1680	1790	1900	1805
Sulfate	<2.5	6.9	8.2	8.3	7.9	8.8
Phosphorus	0.68					
Sulfur	0.69	1.88	3.39	2.74	3.82	3.77
Magnesium	0.74	5.84	10.72	7.13	150.8	2.54
Silicon	0.35	40.42	54.53	56.39	43.16	6.06
Sodium	1528	1458	1461	1471	1655	1505
Aluminum	0	3.82	4.39	3.8	2.77	2.97
Calcium	5.32	491.2	514.8	519.5	738	251
Cadmium						
Cobalt	0	0.4	0.11	34.06	0.52	0.35
Nickel	0.04	6.94	6.08	24.52	13.34	50.45
Potassium	15.09	69.5	23.96	20.52	20.34	17.29
Manganese	0.01	21.15	17.38	24.53	32.21	12.28
Iron	0.05	586.7	580.4	950.5	219.2	61.62
Chromium	0.01	4.64	3.1	2.02	1.12	3.89

Magnesium concentrations increased slightly for all runs, except for the Clinochlore spiked experiment (Run #414) in which the shift was considerable. Clinochlore contains magnesium, thus the increase in magnesium is consistent with both the bulk mineralogy and the geochemical modelling.

Silicon concentrations increased for all autoclave runs. The concentrations in run #437, the control experiment, increased to a value which is in equilibrium with quartz. The concentrations in the other runs were significantly above quartz saturation values.

Aluminum concentrations increased in all samples due to dissolution of the silicate minerals.

The variation in chloride concentration is normal when IC (Ion chromatography) is used to measure higher chloride concentrations.

Sulphate and total sulphur concentrations are essentially the same for all samples and probably indicated that a small amount of gypsum (calcium sulphate) was present in the siliciclastic formation mineralogy. This gypsum dissolved and raised the amount of sulphur in the water.

The increase in iron, chromium, manganese, nickel and cobalt values are from the autoclave metal, and do not represent reactions between the fluid and the formation mineralogy or the minerals spikes.

The increase in all of the components clearly indicate that dissolution of the formation mineralogy and the mineral spike are taking place. Examination using SOLMINEQ.88 pc/shell, a geochemical program used to evaluate water compositions, indicates that all of the waters are slightly supersaturated with calcite, and all of the spiked runs are supersaturated with quartz. The calcite supersaturation is caused by the loss of a small amount of carbon dioxide from the water before the water analysis is made. This shifts the pH to slightly more basic levels, resulting in an apparent calcite supersaturation. The supersaturation of quartz can only occur when the dissolution rate of the spiked phases (albite, clinochlore, labradorite and microcline) occurs more rapidly than the precipitation rate of quartz or other possible product minerals.

6.3 KINETICS

As expected, the rates of reaction at room temperature are slow. The rates at which Al-bearing silicates dissolve in the laboratory, under STP conditions, varies between 1 x 10^{-10} and 1 x 10^{-13} mol (Si)/m^2/sec, depending upon the type of silicate (Kirkwood and Nesbitt, 1990, see Table 7). Of the minerals that consume acid upon dissolution, feldspars and biotites dissolve more rapidly than muscovitic micas and some chlorites. Dissolution rates of clay minerals such as smectites and illites generally have not been given the same detailed laboratory study as feldspars or micas, consequently, their laboratory dissolution rates generally are not well established. Field studies of weathering processes, however, indicate that the clay minerals generally are more reactive than feldspars or micas where contacted by waters undersaturated in the clay minerals. In fact, there is abundant evidence that the clay minerals control solution compositions in sedimentary basins such as the Illinois Basin (Nesbitt, 1980, 1985) and the Western Canada Basin (Hutcheon and Abercombie, 1992). These field studies suggest that reaction rates for dissolution of clay minerals are at the high end of the reaction rate spectrum (values quoted above for the other silicate minerals); consequently, reaction rates of the order of 1x10^{-9} to 1x10^{-10} mol(Si)/m^2/sec for dissolution of the clay minerals such as smectites, vermiculites, septachlorites and illites are reasonable.

Field studies of catchments now being weathered indicates that bulk release rates of elements (from the catchments) are 1 to 3 orders of magnitude lower than predicted if dissolution alone were operative. (Cleaves et al., 1985; Velbel, 1985; Kirkwood and

Nesbitt, 1990). These results have been interpreted to indicate that dissolution rates of silicate minerals are lower in nature than in the laboratory, the assumption being that the reactions taking place in the catchments are the same as occurred in the laboratory. The implication is that the laboratory dissolution rates are inapplicable to nature (Paces, 1983). An alternative, and equally or more likely explanation is that different reactions occur in the catchments than in the laboratory (Nesbitt and Young. 1984; Kirkwood and Nesbitt, 1990).

Clay minerals formation is common in catchments, thus element release is retarded by formation of secondary clay minerals at the expense of dissolution of feldspars and other silicate minerals. Furthermore, the effects of cation exchange reactions on release rates from the catchments generally have not been considered. Since the reactions controlling element release from catchments generally are not well studied, implied dissolution rates derived from catchment studies are suspect in the extreme. By contrast, laboratory dissolution rates are well documented and should be used in modelling. The reaction of acids with silicate minerals including feldspars, micas and clay minerals. If secondary minerals form during dissolution of these minerals, reaction rates of formation of secondary minerals should be included in the calculations, rather than using "quasi-reaction rates" derived from catchment studies.

It was thought that the high pressures of CO_2 used in our autoclave experiments (described above) might accelerate the reactions. On the contrary, the rates of reaction observed in this study are in line with those quoted above.

6.4 VALIDATION

The geochemical modelling predicted the changes which would occur as the system evolved towards and reached the final equilibrium between the minerals, carbon dioxide, water and the dissolved constituents. The experiments never reached final equilibrium; the changes in solids were small and the total amount of dissolved carbon dioxide was small relative to the total amount. However, the few changes in mineralogy which occurred during the autoclave experiments are consistent with the geochemical modelling and the water chemistry. The quartz overgrowths observed by SEM, the formation of illite and kaolinite observed by X-ray and the changes in dissolved cation and anion concentrations observed are in agreement with the modelling. The X-ray data indicated that some new minerals were forming, but insufficient amounts were present to determine which phases they were.

Clearly the amount of time necessary for equilibrium to occur, or even sufficient reactions to occur, is greater than the elapsed experimental run time. However, the experiments did show conclusively that:

- The formation will react and dissolve into the formation water when excess carbon dioxide is introduced.
- The spiked experiments did dissolve more carbon dioxide than the formation did by itself. This agrees with the modelling which showed that reaction with complex silicate minerals controls the amount of carbon dioxide which can be dissolved.
- The autoclave experiments need much longer than four weeks to come to equilibrium. Similar or longer times would be expected during injection in the sub-surface, thus little or no near well damage due to precipitation would occur.

The limited amount of reactions which did occur, agree with the initial portions of each of the geochemical modelling results which were presented earlier. Unfortunately the slow reaction kinetics at low temperatures preclude more detailed comparison.

7.0 CONCLUSIONS

7.1 SYSTEM OVERVIEW

Aquifer disposal of power plant CO_2 is dependent upon the nearby availability of suitable aquifers and the economics of CO_2 capture, compression and purification. Much optimizing is required to minimize capture and compression costs, but pipeline and well systems appear relatively straightforward with several environmental concerns, such as aquitard cementing, still to be addressed.

The costs of pipeline and well systems are but a small part of those of the overall CO_2 disposal system in this Alberta setting, and generally such systems will follow conventional oil and gas practices.

7.2 AQUIFER OVERVIEW

Aquifer disposal of CO_2 in the region between the Genesee and Sundance power stations, west of Edmonton, Alberta, Canada, has been investigated by identifying potential aquifers. The depths of the selected disposal formations (Lower Mannville and Wabamun) are greater than 1400 metres and permit injection pressures of liquid CO_2 greater than 15 MPa. These aquifers are deep enough to be part of the regional flow systems, isolated from the surface by extensive regional aquitards, yet relatively shallow in order to minimize drilling costs.

7.3 NUMERICAL SIMULATION OF AQUIFER INJECTABILITY

There is potential for subsurface disposal of liquid CO_2 both in the Wabamun carbonate aquifer and in the Lower Mannville siliciclastic aquifer in the Wabamun Lake area, Alberta. Our conclusions are based on the modelling of the Lower Mannville aquifer. By choosing a 4" radius injector and completing the entire thickness of the aquifer, an average CO_2

injection rate of 180 t/day can be achieved over a period of 30 years. The CO_2 injection rate decreased as the completion interval of the injector decreased. There is very little effect on the CO_2 injection rate by choosing a 3" radius injector. Injecting CO_2 in the high-permeability region of the aquifer as the CO_2 injection rate increased 10 fold as the absolute permeability of the aquifer increased by an order of magnitude to over 1500 ton/day.

Injecting CO_2-rich water is not a feasible alterative to injecting liquid CO_2.

Although the Wabamun limestone was not modelled, a similar injectivity is expected.

7.4 MODELLING OF CO_2 RESERVOIR REACTIONS

Based upon formation water analyses from 754 wells within the area, two waters (a brine formation water and a brackish formation water) were selected to illustrate extremes for modelling purposes. Three general types of formation mineralogy were chosen; an inert or mineral-absent formation, a carbonate formation, and a siliciclastic formation. The mineralogy of the carbonate formation included the minerals calcite, dolomite and minor amounts of quartz, and represent a typical Devonian carbonate sequence (Wabamun Group) in the area of the Sundance and Genesee power plants. The modelling examined the effects of varying the amounts of these three minerals. The mineralogy of the siliciclastic formation was initially chosen to represent the Lower Mannville Group in the area, but was extended to allow examination of the effects of each of a calcium, magnesium, sodium and potassium aluminosilicate dominant formation mineralogy.

The modelling results indicate that brackish and dilute formation waters can take up more CO_2 than brine formation waters. Thus, brackish or dilute formation waters are favoured for CO_2 capture. The maximum solubility of CO_2 is limited in brines due to the salting-out effect at higher ionic strengths.

The reaction of the mineralogy and formation water for a carbonate aquifer with injected CO_2 does not significantly increase the CO_2 uptake. However, if the carbonate aquifer contains significant amounts of clays with a large cation exchange capacity, the CO_2 capture capacity will be significantly greater than a clay-absent carbonate aquifer.

The maximum amount of CO_2 can be trapped in a siliciclastic aquifer containing a brackish formation water. The amount of trapped CO_2 is dependent upon the amount of and type of basic minerals (feldspars and clays) present in the formation. Magnesium- and calcium-rich siliciclastic aquifers are favoured for neutralization and trapping of the injected CO_2 through the precipitation of calcite (calcium carbonate), dolomite (calcium magnesium carbonate) or magnesite (magnesium carbonate). The amount of captured CO_2 can be increased by neutralization and precipitation by more than a factor of two over solubility in a brackish formation water, depending upon the amount of available calcium and/or magnesium in the formation minerals and the pressure of CO_2. Sodium-rich siliciclastic aquifers will absorb CO_2, neutralizing it to form bicarbonate ions and thus converting the brackish chloride formation water to a bicarbonate brine. The increase in CO_2 solubility due to formation of bicarbonate is only partially balanced by the salting out effect due to the increased ionic strength. Thus a sodium-rich formation mineralogy may be favoured as a disposal site when the precipitation of carbonate minerals must be avoided. Potassium-rich siliciclastic aquifers equilibrate more rapidly than their sodium counterparts and only limited amounts of bicarbonate ion is formed. Thus CO_2 capture is not enhanced significantly for potassium-rich siliciclastic aquifers.

7.5 VALIDATION OF GEOCHEMICAL MODELLING

The geochemical modelling predicted the changes which would occur as the system evolved towards and reached the final equilibrium between the minerals, carbon dioxide, water and the dissolved constituents. The autoclave experiments never reached final equilibrium; the changes in solids were small and the total amount of dissolved carbon dioxide was small relative to the total possible amount. However, the few changes in mineralogy which occurred during the autoclave experiments are consistent with the geochemical modelling and the water chemistry. The quartz overgrowths observed by SEM, the formation of illite and kaolinite observed by X-ray and the changes in dissolved cation and anion concentrations observed are in agreement with the modelling. The X-ray data indicated that some new minerals were forming, but insufficient amounts were present to determine which phases they were.

Clearly the amount of time necessary for equilibrium to occur, or even sufficient reactions to occur, is greater than the length of the experiments. Thus modelling is essential in order to predict long term effects of injection fluid, formation fluid and formation mineral reactions.

The implications of the experiments on subsurface injection is positive. Slow reaction rates imply that only a very limited amount of reaction will occur in the near well region, and that the dominate reaction type in this region will be dissolution. Thus, porosity and permeability will be enhanced in the near well region and injectivity will improve. Over a longer time period, the anticipated complex trapping reactions will occur at some distance from the well. This will form a partial zone of reduced permeability limiting the ultimate migration of carbon dioxide.

8.0 RECOMMENDATIONS

The petrophysics, formation water chemistry and mineralogy of the aquifers in the vicinity of Sundance and Genesee should be more accurately characterized. Only single well injection of liquid CO_2 has been considered. Injection rates of up to 1000 metric tons daily are sustainable over the life cycle of a power plant. Rates that are an order of magnitude larger, are needed to dispose of all the CO_2 produced by a single power plant. This would require 10 wells injecting at the same rates. Multi-well injection patterns should be optimized through more detailed numerical modelling of aquifers in the Sundance and Genesee areas. The effect of injection on the basin flow should also be considered.

One concern which has not been addressed is that the most efficient capture mechanisms are those in which carbonate minerals precipitate, which may reduce the permeability of the reservoir. The detailed examination of permeability changes is beyond the scope of this paper, as these changes depend upon the permeability and the porosity of the aquifer, the amount and surface area of the reactive minerals available, the kinetics of the reactions and on attachment mechanisms of the newly formed minerals, especially the carbonate minerals. This is not the case in carbonate aquifers because only dissolution occurs. The porosity and permeability must increase in these reservoirs as CO_2 is injected. The net change in porosity can be calculated for siliciclastic aquifers but the permeability can not. However, in the early stage of reaction in the siliciclastic reservoirs, dissolution is the predominant mechanism. From this, we can conclude that in the near well region of a CO_2 injection well, permeability and porosity should increase.

Resolution of the permeability changes in a siliciclastic reservoir can only be addressed by physical simulation using core plugs under the actual conditions of aquifer disposal; where CO_2-charged water would be flowed through an aquifer core at different rates and the permeability changes monitored as a function of time. Planning of the experiments can be guided by the existing kinetic data. Then, dissolution of clay minerals and other silicates of the Western Canada Basin in the presence of abundant CO_2 can be modelled using laboratory reaction rates calibrated in the autoclave experiments. Only in this manner can absolute reaction time be assessed.

The reactions considered in this 1992/93 study have been numerically simulated using a closed system reaction type of geochemical model in which the calculation is normalized to one litre of water. These calculations are limited because they assume a closed reaction environment. In reality, CO_2 disposal should be modelled in the context of the hydrodynamics of a sedimentary basin. In a sedimentary basin, deep groundwater moves on the order of one centimetre to one metre a year. The basins are hundreds of kilometres across, so basinal water movement is measured in thousands of years. During that time, the CO_2-charged formation waters will be exposed to a much larger mass of solids than assumed for the modelling carried out here. Consequently, over periods of thousands of years, the reaction between the *basic* minerals in the aquifers will be responsible for capture of more CO_2 than predicted by our model calculations. This will limit the mobility of the CO_2 to a smaller radius than would otherwise be expected and could replace stratigraphic traps. These effects of an open system should be evaluated and included as part of any aquifer model used for assessing the long-term effects of CO_2 aquifer disposal.

Aquifer disposal of CO_2 should only be considered in a system context. In addition to the above, further geological and geochemical work is required to pinpoint disposal and monitoring well locations. Also, overall system concepts and costs should be developed starting from one or more power plants for a specific disposal scheme. In effect, a feasibility level study is needed of all system elements from environmental and permitting through to reservoir characteristics over time, in order to properly define the potential economics of aquifer disposal of CO_2 in a Lake Wabamun area context.

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Open File Report 1994 - 16B

Appendices to Aquifer Disposal of CO_2 - Rich Gases Phase 1

APPENDICES TO AQUIFER DISPOSAL OF CO_2-RICH GASES

Phase I

IN THE VICINITY OF THE SUNDANCE AND GENESEE POWER PLANTS

Injectivity, Chemical Reactions and Proof of Concept

by

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C-1993-5

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TABLE OF CONTENTS

APPENDICES

APPENDIX 11.3.1

Cored Intervals for Aquifers of Interest

CORED INTERVALS

(ARC-DB code) (m depth) (m depth) (m).

SITID	Land Location	Date		Top	bottom	length
73444	00/11-11-049-03W5/0	19791109	1	1610.000	1628.000	17.100
151481	00/11-14-049-03W5/0	19880219	1	1596.000	1605.750	9.750
73454	00/16-21-049-03W5/0	19810312	1	1606.000	1623.600	15.800
73454	00/16-21-049-03W5/0	19810315	2	1623.600	1641.200	18.000
73460	00/10-28-049-03W5/0	19801006	3	1601.500	1610.000	8.500
73460	00/10-28-049-03W5/0	19801004	2	1584.000	1601.500	17.000
73460	00/10-28-049-03W5/0	19801003	1	1566.000	1584.000	18.000
73466	00/07-29-049-03W5/0	19790604	1	1613.000	1622.000	6.600
73466	00/07-29-049-03W5/0	19790605	2	1622.000	1640.000	17.800
73470	00/14-29-049-03W5/0	19830312	1	1611.500	1629.500	18.000
73475	00/03-31-049-03W5/0	19810217	1	1623.000	1641.000	18.000
73484	00/08-33-049-03W5/0	19811117	1	1597.000	1613.000	14.600
73486	00/06-34-049-03W5/0	19810919	2	1594.200	1595.000	0.500
73486	00/06-34-049-03W5/0	19810918	1	1582.000	1594.200	12.200
73486	00/06-34-049-03W5/0	19810922	4	1609.500	1622.000	12.500
73486	00/06-34-049-03W5/0	19810921	3	1595.000	1609.500	14.500
73505	00/10-04-049-04W5/0	19740626	3	1749.900	1761.400	11.600
73549	02/06-14-049-04W5/0	19840530	1	1686.000	1704.000	18.000
73570	02/16-18-049-04W5/0	19840926	1	1775.000	1793.300	18.300
73591	00/14-25-049-04W5/0	19830114	1	1634.000	1649.500	15.500
73594	02/06-28-049-04W5/0	19831231	1	1677.000	1695.000	18.000
73598	00/11-29-049-04W5/0	19781003	1	1722.000	1739.200	13.400
138155	00/06-34-049-04W5/0	19861118	1	1632.000	1644.000	11.510
73606	00/11-36-049-04W5/0	19810521	1	1618.400	1636.000	15.300
151483	00/02-03-049-05W5/0	19870927	1	1747.000	1758.500	11.500
151484	02/14-13-049-05W5/0	19880622	2	1740.250	1747.500	4.700
151484	02/14-13-049-05W5/0	19880621	1	1733.000	1740.250	7.100
73666	02/16-14-049-05W5/0	19840604	2	1755.000	1765.000	10.000
73666	02/16-14-049-05W5/0	19840604	1	1726.000	1744.000	18.000
151486	02/08-23-049-05W5/0	19871101	1	1740.000	1752.500	12.500
138170	00/11-24-049-05W5/0	19870223	2	1737.000	1738.500	1.500
138170	00/11-24-049-05W5/0	19870223	1	1729.000	1739.450	10.450
138171	00/14-26-049-05W5/0	19851030	1	1730.200	1747.700	17.500
73715	00/08-31-049-05W5/0	19570411	4	1748.000	1754.100	
73715	00/08-31-049-05W5/0	19570412	5	1761.700	1764.800	
73715	00/08-31-049-05W5/0	19570413	6	1767.200	1768.800	
138182	00/14-35-049-05W5/0	19861202	2	1715.000	1717.500	1.120
138182	00/14-35-049-05W5/0	19861201	1	1697.000	1715.000	17.900
78124	00/10-02-050-03W5/0	19810302	1	1564.000	1581.500	17.500
78124	00/10-02-050-03W5/0	19810304	2	1581.500	1600.000	18.000
78129	00/01-06-050-03W5/0	19810504	1	1590.000	1608.000	18.000
78129	00/01-06-050-03W5/0	19810505	2	1608.000	1626.000	18.000
78134	00/06-07-050-03W5/0	19821231	1	1557.000	1564.000	6.700
78134	00/06-07-050-03W5/0	19830101	2	1564.000	1577.500	13.500
78139	00/06-18-050-03W5/0	19830223	2	1538.000	1556.000	18.000
78147	00/06-01-050-04W5/0	19820226	1	1590.000	1608.000	17.800
78149	02/08-01-050-04W5/0	19811116	1	1587.000	1605.000	18.000
78152	00/08-02-050-04W5/0	19811005	1	1620.000	1638.000	18.000
78156	00/16-02-050-04W5/0	19820325	2	1637.000	1648.000	11.000
78156	00/16-02-050-04W5/0	19820324	1	1619.000	1637.000	18.000
78157	00/16-03-050-04W5/0	19811104	1	1621.000	1639.000	18.000
78160	00/16-08-050-04W5/0	19791114	1	1585.500	1603.500	18.000
78160	00/16-08-050-04W5/0	19791115	2	1603.500	1621.500	18.000
78162	00/07-09-050-04W5/0	19750812	1	1586.800	1605.100	18.300
78164	00/08-11-050-04W5/0	19830925	1	1586.000	1601.500	15.500
78170	00/14-12-050-04W5/0	19821031	1	1559.000	1577.000	18.000
78173	00/08-14-050-04W5/0	19840726	1	1548.000	1560.000	11.450
78174	00/06-15-050-04W5/0	19840325	1	1570.000	1576.500	6.500
78175	00/16-15-050-04W5/0	19831231	1	1553.000	1563.200	9.300
78186	00/16-24-050-04W5/0	19830619	1	1545.000	1550.000	5.000
78186	00/16-24-050-04W5/0	19830619	2	1550.000	1568.000	18.000
78194	00/10-28-050-04W5/0	19770929	1	1566.700	1585.000	18.300
78197	00/14-29-050-04W5/0	19811205	2	1608.000	1613.300	3.300
78197	00/14-29-050-04W5/0	19811204	1	1590.000	1608.000	17.800
78201	00/09-30-050-04W5/0	19810901	1	1609.000	1618.000	7.500
78201	00/09-30-050-04W5/0	19810902	2	1618.000	1630.000	10.700
78206	00/16-31-050-04W5/0	19840212	1	1592.000	1610.000	18.000
78207	00/02-32-050-04W5/0	19830809	1	1605.000	1608.500	3.500
78207	00/02-32-050-04W5/0	19830809	2	1608.500	1620.000	11.500
78213	00/10-33-050-04W5/0	19770624	2	1585.600	1594.400	8.500
78213	00/10-33-050-04W5/0	19770623	1	1568.200	1585.600	17.100
78222	00/14-03-050-05W5/0	19850713	1	1627.400	1644.400	15.300
78230	00/07-11-050-05W5/0	19740619	1	1603.900	1619.700	15.500
78231	00/05-12-050-05W5/0	19790909	2	1662.000	1673.800	11.800
78231	00/05-12-050-05W5/0	19790907	1	1644.000	1662.000	18.000
78236	00/10-23-050-05W5/0	19790609	1	1609.000	1627.000	13.100
78236	00/10-23-050-05W5/0	19790610	2	1627.500	1645.500	18.000
78240	00/03-24-050-05W5/0	19810223	2	1565.000	1579.000	14.000
78240	00/03-24-050-05W5/0	19810222	1	1547.000	1565.000	18.000
78243	00/16-25-050-05W5/0	19850513	2	1638.000	1645.750	7.100
78243	00/16-25-050-05W5/0	19850513	1	1620.000	1638.000	18.000
138478	00/06-36-050-05W5/0	19851210	2	1622.000	1628.000	5.700
138478	00/06-36-050-05W5/0	19851209	1	1604.000	1622.000	18.000
78247	00/08-36-050-05W5/0	19850317	2	1615.000	1618.500	3.400
78247	00/08-36-050-05W5/0	19850316	1	1597.000	1615.000	17.900
80735	00/13-03-051-04W5/0	19790226	1	1571.000	1582.000	10.800
80744	00/06-05-051-04W5/0	19830618	1	1584.000	1602.000	18.000
80748	00/05-08-051-04W5/0	19780619	1	1971.400	1971.800	0.400
80748	00/05-08-051-04W5/0	19780620	2	1973.900	1986.100	9.900
80758	00/16-09-051-04W5/0	19810201	1	1580.000	1582.500	2.500
80758	00/16-09-051-04W5/0	19810202	2	1582.500	1595.000	12.500
80762	00/06-10-051-04W5/0	19771021	3	1578.300	1587.700	9.400
80762	00/06-10-051-04W5/0	19771020	2	1560.000	1578.300	18.300
80768	00/06-11-051-04W5/0	19820125	2	1573.000	1588.500	15.500
80768	00/06-11-051-04W5/0	19820124	1	1550.000	1573.000	18.000
80775	00/04-14-051-04W5/0	19780621	1	1951.600	1969.900	18.300
80782	00/13-15-051-04W5/0	19821004	1	1629.000	1647.000	18.000
80795	00/16-16-051-04W5/0	19821211	2	1599.000	1617.000	18.000
80799	00/08-18-051-04W5/0	19820112	1	1581.000	1595.500	14.500
80801	00/16-18-051-04W5/0	19810917	1	1601.000	1619.000	18.000
80811	00/14-21-051-04W5/0	19820502	1	1607.000	1625.000	18.000
80826	00/10-29-051-04W5/0	19771111	3	1595.600	1597.200	1.200
80826	00/10-29-051-04W5/0	19771112	4	1597.200	1604.500	7.300
80826	00/10-29-051-04W5/0	19771111	2	1586.500	1595.600	8.800
80826	00/10-29-051-04W5/0	19771110	1	1577.300	1586.500	9.100
80827	00/01-34-051-04W5/0	19781029	1	1566.000	1581.000	15.000
80828	00/11-34-051-04W5/0	19770803	2	1552.300	1556.900	4.000
80828	00/11-34-051-04W5/0	19770804	4	1568.500	1575.200	6.400
80828	00/11-34-051-04W5/0	19770803	3	1556.900	1568.500	11.000
80828	00/11-34-051-04W5/0	19770805	5	1575.200	1589.800	14.500
80828	00/11-34-051-04W5/0	19770802	1	1534.100	1552.300	17.800
82303	00/16-07-052-05W5/0	19820306	2	1655.000	1659.800	4.200
82303	00/16-07-052-05W5/0	19820306	1	1645.000	1655.000	10.000
82307	00/01-18-052-05W5/0	19810109	1	1630.200	1640.100	9.600
82307	00/01-18-052-05W5/0	19810110	2	1640.100	1658.000	17.000
82308	00/06-18-052-05W5/0	19811223	2	1659.200	1664.500	5.200
82308	00/06-18-052-05W5/0	19811222	1	1651.000	1659.200	8.200
82308	00/06-18-052-05W5/0	19811224	3	1664.500	1678.800	14.200
82310	00/16-18-052-05W5/0	19560409	4	1617.900	1656.900	
82310	00/16-18-052-05W5/0	19560409	5	1663.600	1678.800	
82310	00/16-18-052-05W5/0	19560419	6	2025.400	2039.100	
82310	00/16-18-052-05W5/0	19560430	7	2333.500	2347.300	

Appendix I

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82310  00/16-18-052-05W5/0  19560511     8    2609.700  2628.000
82310  00/16-18-052-05W5/0  19560518     9    2699.000  2708.100
82310  00/16-18-052-05W5/0  19560520    10    2742.300  2769.100
82314  00/05-21-052-05W5/0  19731201     1    1595.600  1608.400  12.500
82314  00/05-21-052-05W5/0  19731202     2    1608.400  1626.700  17.700
```

APPENDIX 11.3.2

Formation Water Analyses for Aquifers of Interest

| AGSWDB WATER ANALYSIS REPORT |

AGSWDB Well site identifier (SITID): 73444 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): -954107

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E79-16954-2

Well identifier	Well name	KB elev.	Gr. elev
0495031111000	NATOMAS GAO PEMBINA 11-11-49-3	770.50	766.20

Interval Sampled from: 1605.00 to: 1630.00 meters KB

Formation Sampled: BNFF

Sample produced by: DST # 2 Sampling point:BOTTOM
DST Recovery
27.00 M OIL-CUT MUD
Date: Sampled: 1979/11/14 Received: 1979/11/16 Analyzed: 1979/12/17

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	1344.	3.441	58.5
K	28900.	43.498	739.1
Ca	691.	2.029	34.5
Mg	207.	1.002	17.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	26250.	43.576	740.4
HCO3	183.	0.177	3.0
SO4	5123.	6.278	106.7

Specific gravity 1.0340 @ 25. C
PH 5.20 @ 21. C
Refractive Index 1.34180 @ 25. C
Resistivity ohm/m 0.13700 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 18360.
Calculated TDS : 50721.
TDS by Evapor. @ 110 C: 64980.
TDS at Ignition : 57380.

Sample appearance:

THE ANALYSIS WAS DETERMINED ON WATER EXTRACTED FROM SLIGHTLY OIL FLECKED MUD AND IS CHARACTERISTIC OF A KCL MUD FILTRATE WATER.

Remarks:

Fe PRESENT [E79-16954-1]:SAMPLED FROM TOP OF FLUID|RESISTIVITY OF THE FILTRATE :0.135 OHM/METERS @25 C|MUD.

| AGSWDB WATER ANALYSIS REPORT |

AGSWDB Well site identifier (SITID): 73444 Chemistry number: 3
AGSWDB Hard copy number (HRDCPNO): -954108

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E79-16955-2

Well identifier	Well name	KB elev.	Gr. elev
0495031111000	NATOMAS GAO PEMBINA 11-11-49-3	770.50	766.20

Interval Sampled from: 1575.00 to: 1600.00 meters KB

Formation Sampled: BNFF

Sample produced by: DST # 3 Sampling point:BOTTOM (DUPL.)
DST Recovery
25.00 M MUD
Date: Sampled: 1979/11/14 Received: 1979/11/16 Analyzed: 1979/12/07

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	2460.	6.726	107.0
K	25200.	40.512	644.5
Ca	741.	2.324	37.0
Mg	79.	0.409	6.5

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	24350.	43.175	686.8
HCO3	317.	0.327	5.2
SO4	4987.	6.527	103.8

Specific gravity 1.0350 @ 25. C
PH 7.80 @ 22. C
Refractive Index 1.34160 @ 25. C
Resistivity ohm/m 0.12600 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 17298.
Calculated TDS : 47611.
TDS by Evapor. @ 110 C: 59380.
TDS at Ignition : 53220.

Sample appearance:

THE ANALYSIS WAS DETERMINED ON WATER EXTRACTED FROM MUD AND IS CHARACTERISTIC OF A KCL MUD FILTRATE.

Remarks:

Fe NIL [E79-16955-1]:SAMPLED FROM TOP OF FLUID (DUPL.)|RESISTIVITY OF FILTRATE |0.135 OHM/METERS @ 25 C|MUD SAMPLE.

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                | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73454   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO): -1128207

CHEMICAL & GEOLOGICAL LAB LTD                  Lab. Sample ID. C81-7800-3

Well identifier  Well name                               KB elev. Gr. elev
0495032116000    PCP PEMBINA 16-21-49-3                     788.10    783.40

Interval Sampled from:   1608.00  to:   1628.00 meters KB

Formation Sampled: BL

Sample produced by: DST #    1                 Sampling point:TOP OF TOOL
  DST Recovery
        169.00 M   OIL-CUT MUD
 Date:   Sampled:  1981/03/19  Received: 1981/03/23  Analyzed: 1981/04/10

                 CATIONS                                    ANIONS
|--------------------------------------|  |--------------------------------------|
| ION  |     mg/l     | %MEQ  | MEQ/L |  | ION  |     mg/l     | %MEQ  | MEQ/L |
|--------------------------------------|  |--------------------------------------|
|Na    |        2160.| 48.795|   94.0|  |Cl    |        1860.| 27.247|   52.5|
|K     |          31.|  0.412|    0.8|  |HCO3  |        1586.| 13.499|   26.0|
|Ca    |          24.|  0.622|    1.2|  |SO4   |         440.|  4.758|    9.2|
|Mg    |          12.|  0.513|    1.0|  |CO3   |         240.|  4.154|    8.0|
|      |             |       |       |  |      |             |       |       |
|--------------------------------------|  |--------------------------------------|

Specific gravity      1.0020 @  25. C   Refractive Index      1.33360 @  25. C
PH                      9.00 @  25. C   Resistivity ohm/m     1.23000 @  25. C
Hydrogen Sulfide Description:
Organics Description             :
Calculated sodium:          2148.       Calculated TDS :            5504.
TDS by Evapor. @ 110 C:          6045.  TDS at Ignition :                4500.

Sample appearance:

CLEAR,COLORLESS FILTRATE RECOVERED FROM WATERY MUD.ORGANICS: PRESENT.

Remarks:

Fe TRACE
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                | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73460   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO): -1078207

CHEMICAL & GEOLOGICAL LAB LTD                  Lab. Sample ID., E80-11529-1

Well identifier  Well name                               KB elev. Gr. elev
0495032810000    COLGAS DOME PEMBINA 10-28-49-3             788.10    784.40

Interval Sampled from:   1576.00  to:   1584.00 meters KB

Formation Sampled: GLC SS

Sample produced by: DST #    1                 Sampling point:DOWNHOLE SAMPLER
  DST Recovery
        495.00 M   CLEAN OIL
        405.00 M   SALT WATER-CUT OIL
         70.00 M   OIL-CUT MUD
 Date:   Sampled:  1980/10/09  Received: 1980/10/15  Analyzed: 1980/11/25

                 CATIONS                                    ANIONS
|--------------------------------------|  |--------------------------------------|
| ION  |     mg/l     | %MEQ  | MEQ/L |  | ION  |     mg/l     | %MEQ  | MEQ/L |
|--------------------------------------|  |--------------------------------------|
|Na    |       27127.| 45.786| 1180.0|  |Cl    |       45400.| 49.690| 1280.6|
|K     |         255.|  0.253|    6.5|  |HCO3  |         305.|  0.194|    5.0|
|Ca    |        1554.|  3.009|   77.5|  |SO4   |         152.|  0.123|    3.2|
|Mg    |         296.|  0.945|   24.4|  |      |             |       |       |
|      |             |       |       |  |      |             |       |       |
|--------------------------------------|  |--------------------------------------|

Specific gravity      1.0490 @  25. C   Refractive Index      1.34550 @  25. C
PH                      6.60 @  22. C   Resistivity ohm/m     0.10600 @  25. C
Hydrogen Sulfide Description:
Organics Description             :
Calculated sodium:         27287.       Calculated TDS :           74839.
TDS by Evapor. @ 110 C:         81560.  TDS at Ignition :               70780.

Sample appearance:

ORGANICS: NIL.A LYNES UNITED DOWNHOLE SAMPLER #75WAS RECIEVERD @5000 KPA. IT C
ONTAINED 20.3 L OF GAS, 587 ML OF OIL & 2.1 L OF WATER.

Remarks:

Fe MUCH
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 73460 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): -1078208

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E80-11530-4

Well identifier	Well name	KB elev.	Gr. elev
0495032810000	COLGAS DOME PEMBINA 10-28-49-3	788.10	784.40

Interval Sampled from: 1604.00 to: 1608.00 meters KB

Formation Sampled: BNFF

Sample produced by: DST # 2 Sampling point:BOTTOM
DST Recovery
100.00 M MUD- AND SALT WATER-CUT OIL
700.00 M OIL-CUT SALT WATER
Date: Sampled: 1980/10/10 Received: 1980/10/15 Analyzed: 1980/11/05

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	33383.	44.889	1452.1
K	595.	0.470	15.2
Ca	2002.	3.088	99.9
Mg	608.	1.547	50.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	56500.	49.265	1593.7
HCO3	809.	0.410	13.3
SO4	514.	0.331	10.7

Specific gravity 1.0620 @ 25. C
PH 6.70 @ 22. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 33745.
TDS by Evapor. @ 110 C: 95720.

Refractive Index 1.34900 @ 25. C
Resistivity ohm/m 0.08800 @ 25. C
Calculated TDS : 93767.
TDS at Ignition : 88720.

Sample appearance:

ORGANICS: NIL.THE SAMPLE CONSISTED OF SLIGHTLY MURKY SALT WATER.

Remarks:

Fe TRACE

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 73466 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): -904202

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID.: E79-10548-3

Well identifier	Well name	KB elev.	Gr. elev
0495032907000	COLGAS ET AL PEMBINA 7-29-49-3	800.80	796.70

Interval Sampled from: 1628.00 to: 1638.00 meters KB

Formation Sampled: BNFF

Sample produced by: DST # 1 Sampling point:BOTTOM
DST Recovery
5.30 M3 SALT WATER
Date: Sampled: 1979/06/08 Received: 1979/06/12 Analyzed: 1979/06/27

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	34094.	44.909	1483.0
Ca	2367.	3.577	118.1
Mg	605.	1.508	49.8

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	57700.	49.285	1627.5
HCO3	698.	0.346	11.4
SO4	595.	0.375	12.4

Specific gravity 1.0660 @ 25. C
PH 7.00 @ 24. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 34107.
TDS by Evapor. @ 110 C: 98700.

Refractive Index 1.34900 @ 25. C
Resistivity ohm/m 0.08500 @ 25. C
Calculated TDS : 95717.
TDS at Ignition : 92200.

Sample appearance:

NA=NA+K. THE SAMPLE CONSISTED OF MURKY SALT WATER.

Remarks:

Fe TRACE

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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73470   Chemistry number:     1
AGSWDB Hard copy number   (HRDCPNO):  -1305512

CHEMICAL & GEOLOGICAL LAB LTD                   Lab. Sample ID. C83-0151-2

Well identifier  Well name                                KB elev. Gr. elev
0495032914000    COLGAS DOME PEMBINA 14-29-49-3              811.50    806.90

Interval Sampled from:    1637.00  to:    1642.50 meters KB

Formation Sampled: BNFF

Sample produced by: DST #     1                  Sampling point:BOTTOM
  DST Recovery
       20.00 M   GAS- AND OIL-CUT MUD
 Date:    Sampled:  1983/03/16  Received: 1983/03/23  Analyzed: 1983/04/04

                CATIONS                                      ANIONS
|------------------------------------|   |------------------------------------|
|  ION   |      mg/l      | %MEQ   | MEQ/L |   |  ION   |      mg/l      | %MEQ   | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na      |           4435.| 47.160|  192.9|   |Cl      |           6450.| 44.476|  181.9|
|K       |             55.|  0.344|    1.4|   |HCO3    |            732.|  2.933|   12.0|
|Ca      |             90.|  1.098|    4.5|   |SO4     |            423.|  2.153|    8.8|
|Mg      |             67.|  1.348|    5.5|   |CO3     |             60.|  0.489|    2.0|
|        |                |       |       |   |        |                |       |       |
|------------------------------------|   |------------------------------------|

Specific gravity      1.0080 @   25. C    Refractive Index     1.33540 @   25. C
PH                      8.60 @   25. C    Resistivity ohm/m    0.42700 @   25. C
Hydrogen Sulfide Description:
Organics Description           :
Calculated sodium:          4477.         Calculated TDS :          11927.
TDS by Evapor. @ 110 C:          14360.   TDS at Ignition :                11270.

Sample appearance:

ORGANICS : MUCH. PALE YELLOW COLORED FILTRATE RECOVERED FROM THE WATER PORTION
 OF THE SAMPLE.

Remarks:

Fe TRACE [C83-0151-1]| DOWN HOLE SAMPLER 187| RESISTIVITY: 1.43 OHM M @ 25 C|
PALE YELLOW COLORED FILTRATE RECOVERED FROM MUD CONTAINING A TRACE OF HYDROCAR
BONS.| THE DOWN HOLE SAMPLER WAS RECEIVED WITH AN OPENING PRESSUR OF 400 KPA @
 23 C| IT CONT AINED 1300 ML MUD ONLY| INSUFFICIENT RECOVERABLE GAS FOR ANALYS
IS.
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73470   Chemistry number:     2
AGSWDB Hard copy number   (HRDCPNO):  -1306102

CHEMICAL & GEOLOGICAL LAB LTD                   Lab. Sample ID. C83-0152-6

Well identifier  Well name                                KB elev. Gr. elev
0495032914000    COLGAS DOME PEMBINA 14-29-49-3              811.50    806.90

Interval Sampled from:    1613.00  to:    1619.00 meters KB

Formation Sampled: OST

Sample produced by: DST #     2                  Sampling point:DOWN HOLE SAMPLE
  DST Recovery
      137.00 M   OIL-CUT MUD
 Date:    Sampled:  1983/03/17  Received: 1983/03/23  Analyzed: 1983/04/04

                CATIONS                                      ANIONS
|------------------------------------|   |------------------------------------|
|  ION   |      mg/l      | %MEQ   | MEQ/L |   |  ION   |      mg/l      | %MEQ   | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na      |           4505.| 48.068|  196.0|   |Cl      |           6450.| 44.628|  181.9|
|K       |             47.|  0.295|    1.2|   |HCO3    |            946.|  3.803|   15.5|
|Ca      |             70.|  0.857|    3.5|   |SO4     |            290.|  1.481|    6.0|
|Mg      |             43.|  0.868|    3.5|   |        |                |       |       |
|        |                |       |       |   |        |                |       |       |
|------------------------------------|   |------------------------------------|

Specific gravity      1.0060 @   25. C    Refractive Index     1.33500 @   25. C
PH                      8.30 @   25. C    Resistivity ohm/m    0.53500 @   25. C
Hydrogen Sulfide Description:
Organics Description           :
Calculated sodium:          4516.         Calculated TDS :          11835.
TDS by Evapor. @ 110 C:          13460.   TDS at Ignition :                 9850.

Sample appearance:

PALE YELLOW COLORED FILTRATE RECOVERED FROM THE WATER PORTION OF THE SAMPLE. T
HE DOWN HOLE SAMPLER WAS RECEIVED WITH AN OPENING PRESSURE OF 0 KPA @ 23 C| IT
 CONTAINED 575 ML MUD AND 625 ML OIL.

Remarks:

Fe TRACE [C83-0152-3]| MIDDLE 1| RESISTIVITY: 0.728 OHM M @ 25 C| PALE YELLOW
COLORED FILTRATE RECOVERED FROM THE WATER PORTION OF THE SAMPLE.| [C83-0152-5]
| BOTTOM| RESISTIVITY: 2.53 OHM M @ 25 C| PALE YELLOW COLORED FILTRATE RECOVER
ED FROM OIL FLE CKED MUD.
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      73475   Chemistry number:     1
AGSWDB Hard copy number    (HRDCPNO):  -1031506

CHEMICAL & GEOLOGICAL LAB LTD                 Lab. Sample ID. C81-7210-5

Well identifier  Well name                               KB elev. Gr. elev
0495033103000    PCP PEMBINA 3-31-49-3                      814.30    809.60

Interval Sampled from:   1660.00  to:   1669.00 meters KB

Formation Sampled: BNFF

Sample produced by: DST #    1                Sampling point:DOWN HOLE SAMPLE
  DST Recovery
        75.00 M   MUD
 Date:    Sampled:  1981/02/24  Received: 1981/02/24  Analyzed: 1981/03/12

                CATIONS                                  ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION  |      mg/l     | %MEQ  | MEQ/L |  |  ION  |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na     |        10900.| 46.885|  474.1|  |Cl     |        16630.| 46.386|  469.1|
|K      |          415.|  1.050|   10.6|  |HCO3   |          708.|  1.147|   11.6|
|Ca     |          480.|  2.369|   24.0|  |SO4    |          379.|  0.780|    7.9|
|Mg     |          170.|  1.383|   14.0|  |       |              |       |       |
|       |              |       |       |  |       |              |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity       1.0200 @  25. C   Refractive Index      1.33800 @  25. C
PH                       7.60 @  24. C   Resistivity ohm/m     0.23900 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:        10361.         Calculated TDS :          28368.
TDS by Evapor. @ 110 C:        29740.    TDS at Ignition :             27780.

Sample appearance:

ORGANICS: PRESENT.PALE YELLOW FILTRATE RECOVERED FROM THE WATER PORTION OF THE
 SAMPLE.

Remarks:

Fe TRACE                  ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      73475   Chemistry number:     2
AGSWDB Hard copy number    (HRDCPNO):  -1031507

CHEMICAL & GEOLOGICAL LAB LTD                 Lab. Sample ID. C81-7248-3

Well identifier  Well name                               KB elev. Gr. elev
0495033103000    PCP PEMBINA 3-31-49-3                      814.30    809.60

Interval Sampled from:   1641.00  to:   1647.00 meters KB

Formation Sampled: ELRS

Sample produced by: DST #    2                Sampling point:BOTTOM
  DST Recovery
       170.00 M   MUD
 Date:    Sampled:  1981/02/25  Received: 1981/02/26  Analyzed: 1981/03/12

                CATIONS                                  ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION  |      mg/l     | %MEQ  | MEQ/L |  |  ION  |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na     |         3250.| 49.095|  141.4|  |Cl     |         4320.| 42.317|  121.9|
|K      |           95.|  0.844|    2.4|  |HCO3   |          610.|  3.472|   10.0|
|Ca     |           47.|  0.814|    2.3|  |SO4    |          407.|  2.943|    8.5|
|Mg     |           18.|  0.514|    1.5|  |       |              |       |       |
|       |              |       |       |  |       |              |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity       1.0040 @  25. C   Refractive Index      1.33400 @  25. C
PH                       8.50 @  23. C   Resistivity ohm/m     0.76700 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:         3138.         Calculated TDS :           8230.
TDS by Evapor. @ 110 C:         8415.    TDS at Ignition :              7865.

Sample appearance:

ORGANICS: PRESENT CLEAR, COLORLESS FILTRATE RECOVERED FROM MUD CONTAINING A TR
ACE OF HYDROCARBONS.

Remarks:

Fe PRESENT                ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73475   Chemistry number:    4
AGSWDB Hard copy number   (HRDCPNO):  -1092406

CHEMICAL & GEOLOGICAL LAB LTD               Lab. Sample ID. E81-3129

Well identifier  Well name                              KB elev. Gr. elev
0495033103000    PCP PEMBINA 3-31-49-3                    814.30    809.60

Interval Sampled from:    1643.00  to:    1646.00 meters KB

Formation Sampled: ELRS

Sample produced by:                           Sampling point:RECOVERY
 Date:    Sampled:  1981/06/25  Received: 1981/06/26  Analyzed: 1981/06/29

                CATIONS                                 ANIONS
|-------------------------------------|  |------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |  |  ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |------------------------------------|
|Na      |      24114.| 45.532| 1048.9|  |Cl      |      40500.| 49.589| 1142.4|
|K       |        269.|  0.299|    6.9|  |HCO3    |        571.|  0.406|    9.4|
|Ca      |       1361.|  2.948|   67.9|  |SO4     |         12.|  0.011|    0.2|
|Mg      |        340.|  1.215|   28.0|  |        |            |       |       |
|        |            |       |       |  |        |            |       |       |
|-------------------------------------|  |------------------------------------|

Specific gravity      1.0420 @  25. C    Refractive Index      1.34420 @  25. C
PH                      6.80 @  26. C    Resistivity ohm/m     0.13500 @  25. C
Hydrogen Sulfide Description:
Organics Description        :
Calculated sodium:       24281.          Calculated TDS :           66775.
TDS by Evapor. @ 110 C:         71200.   TDS at Ignition :                65560.

Sample appearance:

ORGANICS : NIL.

Remarks:

Fe TRACE
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73484   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):  -1209301

CHEMICAL & GEOLOGICAL LAB LTD               Lab. Sample ID. E81-9364-4

Well identifier  Well name                              KB elev. Gr. elev
0495033308000    AMOCO PEMBINA 8-33-49-3                  807.40    803.10

Interval Sampled from:    1615.00  to:    1621.00 meters KB

Formation Sampled: OST

Sample produced by: DST #    1               Sampling point:DOWNHOLE SAMPLER
  DST Recovery
        18.00 M    OIL-CUT MUD
 Date:    Sampled:  1981/11/20  Received: 1981/11/23  Analyzed: 1981/12/08

                CATIONS                                 ANIONS
|-------------------------------------|  |------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |  |  ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |------------------------------------|
|Na      |      21463.| 45.021|  933.6|  |Cl      |      36100.| 49.103| 1018.2|
|K       |        400.|  0.493|   10.2|  |HCO3    |        566.|  0.447|    9.3|
|Ca      |       1401.|  3.371|   69.9|  |SO4     |        455.|  0.457|    9.5|
|Mg      |        279.|  1.107|   23.0|  |        |            |       |       |
|        |            |       |       |  |        |            |       |       |
|-------------------------------------|  |------------------------------------|

Specific gravity      1.0420 @  25. C    Refractive Index      1.34400 @  25. C
PH                      7.50 @  21. C    Resistivity ohm/m     0.12200 @  25. C
Hydrogen Sulfide Description:
Organics Description        :
Calculated sodium:       21707.          Calculated TDS :           60221.
TDS by Evapor. @ 110 C:         61940.   TDS at Ignition :                57680.

Sample appearance:

A LYNES UNITED DOWNHOLE SAMPLER 180 WAS RECEIVED AT 255 KPA.IT CONTAINED GAS A
ND 1.8 L. OF VERY MUDDY SALT WATER.ORGNAICS: NIL.

Remarks:

Fe NIL [E81-9364-1]:|SAMPLED FROM 9.5M ABOVE TOOL.|MUD,NO ANALYSIS ATTEMPTED.|
[E81-9364-2]:|SAMPLED FROM TOP OF TOOL.|MUD,NO ANALYSIS ATTEMPTED.
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                    | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73486   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):  -1183211

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. C81-10724-2

Well identifier  Well name                             KB elev. Gr. elev
0495033406000    COLGAS DOME PEMBINA 6-34-49-3            800.50    796.80

Interval Sampled from:   1602.00  to:   1614.00 meters KB

Formation Sampled: BNFF

Sample produced by: DST #    1                Sampling point:TOP
  DST Recovery
         1.00 M   CLEAN CONDENSATE
         1.00 M   SALT WATER
 Date:   Sampled:  1981/09/25  Received: 1981/09/29  Analyzed: 1981/10/29

                CATIONS                                  ANIONS
|----------------------------------------|  |----------------------------------------|
|  ION  |     mg/l      | %MEQ  | MEQ/L  |  |  ION  |     mg/l      | %MEQ  | MEQ/L  |
|----------------------------------------|  |----------------------------------------|
|Na     |        32400.| 43.481| 1409.3|  |Cl     |        57450.| 49.996| 1620.5|
|K      |          563.|  0.444|   14.4|  |HCO3   |          500.|  0.253|    8.2|
|Ca     |         2302.|  3.544|  114.9|  |SO4    |          430.|  0.276|    9.0|
|Mg     |          790.|  2.006|   65.0|  |       |              |       |       |
|       |              |       |       |  |       |              |       |       |
|----------------------------------------|  |----------------------------------------|

Specific gravity       1.0600 @  25. C   Refractive Index      1.34800 @  25. C
PH                       7.30 @  25. C   Resistivity ohm/m     0.08900 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:        33516.         Calculated TDS :           94734.
TDS by Evapor. @ 110 C:       99000.     TDS at Ignition :              89110.

Sample appearance:

CLEAR, COLORLESS FILTRATE RECOVERED FROM A SAMPLE CONTAINING A TRACE SEDIMENT.
 ORGANICS: TRACE.

Remarks:

Fe PRESENT
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                    | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73505   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):   -458104

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID.'E74-2232-2

Well identifier  Well name                             KB elev. Gr. elev
0495040410000    CS KEY PEM 10-4-49-4                     851.00    847.30

Interval Sampled from:   1565.15  to:   1588.62 meters KB

Formation Sampled: BR

Sample produced by: DST #    6                Sampling point:
  DST Recovery
        77.40 M   MUD
       109.70 M   GAS-CUT MUD
       382.80 M   WATER
        31.70 M   MUD-CUT WATER
 Date:   Sampled:  1974/07/01  Received: 1974/07/04  Analyzed: 1974/07/17

                CATIONS                                  ANIONS
|----------------------------------------|  |----------------------------------------|
|  ION  |     mg/l      | %MEQ  | MEQ/L  |  |  ION  |     mg/l      | %MEQ  | MEQ/L  |
|----------------------------------------|  |----------------------------------------|
|Na     |        10977.| 48.139|  477.5|  |Cl     |        17000.| 48.344|  479.5|
|Ca     |          240.|  1.207|   12.0|  |HCO3   |          960.|  1.586|   15.7|
|Mg     |           78.|  0.647|    6.4|  |SO4    |           36.|  0.076|    0.7|
|       |              |       |       |  |       |              |       |       |
|----------------------------------------|  |----------------------------------------|

Specific gravity       1.0230 @  16. C   Refractive Index      1.33820 @  25. C
PH                       7.50 @  27. C   Resistivity ohm/m     0.24000 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:        10981.         Calculated TDS :           28807.
TDS by Evapor. @ 110 C:       30140.     TDS at Ignition :              26150.

Sample appearance:

ANALYSIS DETERMINED ON COLORLESS WATER SAMPLE RECOVERED FROM MUDDY WATER SAMPL
E.

Remarks:

Fe PRESENT [E74-2232-1]:TOP|RES:2.57 OHM/M @ 25 C.|COLORLESS WTR RECOVERED FRO
M MUD|[E74-2232-3]:BOTTOM|RES: 0.240 OHM/M @ 25 C.|COLORLESS WATER RECOVERED F
ROM MUDDY WATER.|[E74-2232-4]:L.U.S. BOTTOM HOLE SAMPLE R.|RECEIVED UNDER A PR
ESSURE OF 130 PSIG.CONTAINED IN THE SAMPLER WAS GAS AND 2100 MLS OF MUD.RES:0.
931 OHM/M @25 C.|COLORLESS WATER RECOVERED FROM MUD SAMPLE.
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73549   Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):  -1545211

CORE LABORATORIES CANADA LT.                  Lab. Sample ID. E84-4915-6

Well identifier  Well name                               KB elev. Gr. elev
0495041406020    WESTAR ET AL PEMBINA 6-14-49-4            821.50    818.20

Interval Sampled from:    1689.00  to:    1693.50 meters KB

Formation Sampled: MISS SYS

Sample produced by: DST #     1               Sampling point:DOWNHOLE SAMPLER
  DST Recovery
        54.00 M   CLEAN OIL
        65.00 M   OIL-CUT MUD
        36.00 M   SALT WATER
 Date:   Sampled:  1984/05/31  Received: 1984/06/01  Analyzed: 1984/06/06

                 CATIONS                                  ANIONS
|------------------------------------|   |------------------------------------|
|  ION   |      mg/l      | %MEQ  | MEQ/L |  |  ION   |      mg/l      | %MEQ  | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na      |         29090.| 45.474| 1265.3|   |Cl      |         47500.| 48.150| 1339.8|
|K       |           386.|  0.355|    9.9|   |HCO3    |           961.|  0.566|   15.7|
|Ca      |          2098.|  3.762|  104.7|   |SO4     |           591.|  0.442|   12.3|
|Mg      |           423.|  1.251|   34.8|   |        |               |       |       |
|        |               |       |       |   |        |               |       |       |
|------------------------------------|   |------------------------------------|

Specific gravity       1.0490 @  25. C   Refractive Index      1.34640 @  25. C
PH                       7.80 @  25. C   Resistivity ohm/m     0.08900 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:        28242.         Calculated TDS :          79327.
TDS by Evapor. @ 110 C:        93800.    TDS at Ignition :              77800.

Sample appearance:

NORTHSTAR TESTERS DOWNHOLE SAMPLER RECEIVED UNDER ATMOSPHERIC PRESSURE AND CON
TAINED 4.3 L OF OIL STAINED SALT WATER.(5% OIL).

Remarks:

Fe MUCH [E84-4915-1]:SAMPLED FROM 155 M ABOVE TOOL.|RESISTIVITY:0.526 OHM METE
RS @25C.|OIL FLECKED MUD.|[E84-4915-4]:SAMPLED FROM 36 M ABOVE TOOL.|RESISTIVI
TY:0.100 OHM METERS @25C.|MURKY WATER.SLIGHT TRACE OF OIL.|[E84-4915-5]:SAMPLE
D FROM ABOVE T OOL.|RESISTIVITY:0.094 OHM METERS @25C.|MURKY WATER.SLIGHT TRAC
E OF OIL.
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73549   Chemistry number:    3
AGSWDB Hard copy number    (HRDCPNO):  -1545302

CHEMEX LABS (ALBERTA) LTD.                    Lab. Sample ID. WFST1101

Well identifier  Well name                               KB elev. Gr. elev
0495041406020    WESTAR ET AL PEMBINA 6-14-49-4            821.50    818.20

Interval Sampled from:    1688.00  to:    1690.00 meters KB

Formation Sampled: MISS SYS

Sample produced by:                           Sampling point:
 Date:   Sampled:  1984/06/21  Received: 1984/07/16  Analyzed: 1984/07/17

                 CATIONS                                  ANIONS
|------------------------------------|   |------------------------------------|
|  ION   |      mg/l      | %MEQ  | MEQ/L |  |  ION   |      mg/l      | %MEQ  | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na      |         27700.| 46.576| 1204.9|   |Cl      |         42600.| 46.448| 1201.6|
|K       |           590.|  0.583|   15.1|   |HCO3    |           337.|  0.213|    5.5|
|Ca      |          1920.|  3.704|   95.8|   |SO4     |           323.|  0.260|    6.7|
|Mg      |           695.|  2.211|   57.2|   |        |               |       |       |
|Fe      |             4.|  0.005|    0.1|   |        |               |       |       |
|------------------------------------|   |------------------------------------|

Specific gravity       1.0570 @   0. C   Refractive Index      1.34800 @   0. C
PH                       6.70 @  25. C   Resistivity ohm/m     0.09800 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:        24391.         Calculated TDS :          70095.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 73549 Chemistry number: 4
AGSWDB Hard copy number (HRDCPNO): -1545303

CORE LABORATORIES CANADA LT. Lab. Sample ID. 7021-84-711

Well identifier	Well name	KB elev.	Gr. elev
0495041406020	WESTAR ET AL PEMBINA 6-14-49-4	821.50	818.20

Interval Sampled from: 1688.00 to: 1690.00 meters KB

Formation Sampled: MISS SYS

Sample produced by: Sampling point:WATER SAMPLE

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	29500.	44.924	1283.2
K	466.	0.417	11.9
Ca	1708.	2.984	85.2
Mg	562.	1.619	46.2

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	50263.	49.635	1417.7
HCO3	446.	0.256	7.3
SO4	225.	0.164	4.7

Specific gravity 1.0590 @ 15. C Refractive Index 1.34560 @ 22. C
PH 6.60 @ 0. C Resistivity ohm/m 0.08500 @ 25. C
Hydrogen Sulfide Description:
Calculated sodium: 29850. Calculated TDS : 82827.

Sample appearance:

NALC EQUIV.83208.

Remarks:

Fe N.D.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 73570 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): -1574112

CORE LABORATORIES CANADA LT. Lab. Sample ID. 7012-84-1762

Well identifier	Well name	KB elev.	Gr. elev
0495041816020	GEI ET AL PEMBINA 16-18-49-4	852.90	848.20

Interval Sampled from: 1771.00 to: 1781.00 meters KB

Formation Sampled: GLC SS

Sample produced by: DST # 2 Sampling point:BOTTOM
DST Recovery
30.00 M GAS-CUT OIL
65.00 M GAS-CUT MUD
Date: Sampled: 1984/09/30 Received: 1984/10/03 Analyzed: 1984/10/09

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	9000.	44.594	391.5
K	143.	0.417	3.7
Ca	472.	2.683	23.6
Mg	239.	2.240	19.7

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	15039.	48.321	424.2
HCO3	679.	1.268	11.1
SO4	201.	0.477	4.2

Specific gravity 1.0180 @ 15. C Refractive Index 1.33560 @ 22. C
PH 7.30 @ 0. C Resistivity ohm/m 0.26000 @ 25. C
Hydrogen Sulfide Description:
Calculated sodium: 9112. Calculated TDS : 25396.

Sample appearance:

NACL EQUIV. 25393.

Remarks:

Fe N D

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                     | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73570   Chemistry number:    2
AGSWDB Hard copy number   (HRDCPNO):  -1574201

CORE LABORATORIES CANADA LT.                 Lab. Sample ID. 7012-84-1762

Well identifier  Well name                               KB elev. Gr. elev
0495041816020    GEI ET AL PEMBINA 16-18-49-4                852.90    848.20

Interval Sampled from:   1725.00  to:   1729.00 meters KB

Formation Sampled: GLC SS

Sample produced by: DST #    3                Sampling point:BOTTOM
  DST Recovery
        22.00 M   FRESH WATER
        90.00 M   MUD- AND GAS-CUT WATER
 Date:   Sampled:  1984/10/01  Received: 1984/10/03  Analyzed: 1984/10/09

               CATIONS                                     ANIONS
|-------------------------------------|   |-------------------------------------|
| ION  |      mg/l     | %MEQ  | MEQ/L |   | ION  |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na    |         2350.| 48.473|  102.2|   |Cl    |         3089.| 41.317|   87.1|
|K     |           26.|  0.315|    0.7|   |HCO3  |         1015.|  7.888|   16.6|
|Ca    |           24.|  0.568|    1.2|   |SO4   |          118.|  1.165|    2.5|
|Mg    |            7.|  0.273|    0.6|   |      |              |       |       |
|      |              |       |       |   |      |              |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity      1.0055 @  15. C   Refractive Index     1.33300 @  22. C
PH                      8.30 @   0. C   Resistivity ohm/m    0.97000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:          2401.       Calculated TDS :            6138.

Sample appearance:

NACL EQUIV. 5836.

Remarks:

Fe N D
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                     | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73591   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):  -1376311

CORE LABORATORIES CANADA LT.                 Lab. Sample ID. 7023-83-27

Well identifier  Well name                               KB elev. Gr. elev
0495042514000    PCP PEMBINA 14-25-49-4                      817.40    812.70

Interval Sampled from:   1661.00  to:   1664.00 meters KB

Formation Sampled: OST

Sample produced by: DST #    1                Sampling point:BOTTOMHOLE SAMPL
  DST Recovery
        59.00 M   GAS-CUT MUD
        20.00 M   OIL-CUT MUD
        95.80 M   WATER
 Date:   Sampled:  1983/01/17  Received: 1983/01/19  Analyzed: 1983/01/25

               CATIONS                                     ANIONS
|-------------------------------------|   |-------------------------------------|
| ION  |      mg/l     | %MEQ  | MEQ/L |   | ION  |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na    |        13200.| 45.263|  574.2|   |Cl    |        21690.| 48.229|  611.8|
|K     |          200.|  0.403|    5.1|   |HCO3  |          882.|  1.140|   14.5|
|Ca    |          656.|  2.581|   32.7|   |SO4   |          477.|  0.783|    9.9|
|Mg    |          247.|  1.602|   20.3|   |      |              |       |       |
|      |              |       |       |   |      |              |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity      1.0268 @  25. C   Refractive Index     1.33920 @  25. C
PH                      7.20 @  25. C   Resistivity ohm/m    0.18000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:         13407.       Calculated TDS :           36911.

Sample appearance:

NACL EQUIVALENT = 36685. INSUFFICENT SAMPLE FOR ROUTINE OIL ANALYSIS.

Remarks:

Fe PRESENT
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73594    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):  -1488304

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. E84-00089-4

Well identifier  Well name                                 KB elev. Gr. elev
0495042806020    ANDEX ET AL PEMBINA 6-28-49-4               813.00    808.90

Interval Sampled from:   1689.00  to:   1726.00 meters KB

Formation Sampled: NORD

Sample produced by: DST #    1               Sampling point:DOWNHOLE SAMPLER
  DST Recovery
       10.00 M   MUD-CUT OIL
       90.00 M   GAS-CUT MUD
 Date:   Sampled:  1984/01/02  Received: 1984/01/05  Analyzed: 1984/01/24

                  CATIONS                                  ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION   |      mg/l      | %MEQ  | MEQ/L |  |  ION   |      mg/l      | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na      |          11990.| 46.263|  521.5|  |Cl      |          18700.| 46.789|  527.5|
|K       |            167.|  0.379|    4.3|  |HCO3    |            778.|  1.131|   12.8|
|Ca      |            529.|  2.342|   26.4|  |SO4     |            831.|  1.535|   17.3|
|Mg      |            214.|  1.562|   17.6|  |        |                |       |       |
|        |                |       |       |  |        |                |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity      1.0220 @  25. C   Refractive Index     1.33860 @  25. C
PH                      8.00 @  22. C   Resistivity ohm/m    0.19100 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:        11806.        Calculated TDS :          32463.
TDS by Evapor. @ 110 C:         32960.  TDS at Ignition :               31070.

Sample appearance:

ORGANICS: TRACE. LYNES UNITED DOWNHOLE SAMPLER 51 RECEIVED UNDER 2410 KPA PRES
SURE. RECOVERED FROM THE CHAMBER WAS GAS AND 50 ML. OF OIL CUT MUDDY WATER.(17
% OIL)

Remarks:

Fe NIL [E84-00089-1]: SAMPLED FROM TOP| RESISTIVITY: 1.28 OHM/METERS @ 25 C.|M
UD.|[E84-00089-2]: SAMPLED FROM MIDDLE: RESISTIVITY:0.240 OHM/METERS @ 25 C.|
OIL CUT MUDDY WATER (20% OIL).
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73598    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):   -835108

CORE LABORATORIES CANADA LT.                     Lab. Sample ID. 7022-857

Well identifier  Well name                                 KB elev. Gr. elev
0495042911000    FOCUS ZEPHYR PEMBINA 11-29-49-4             828.00    823.60

Interval Sampled from:   1727.00  to:   1730.00 meters KB

Formation Sampled: OST

Sample produced by:                              Sampling point:SWABBING
 Date:   Sampled:  1978/11/16  Received: 1978/11/20  Analyzed: 1978/12/01

                  CATIONS                                  ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION   |      mg/l      | %MEQ  | MEQ/L |  |  ION   |      mg/l      | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na      |          16800.| 44.013|  730.8|  |Cl      |          29202.| 49.610|  823.7|
|K       |            400.|  0.616|   10.2|  |HCO3    |            327.|  0.323|    5.4|
|Ca      |           1756.|  5.278|   87.6|  |SO4     |             53.|  0.066|    1.1|
|Mg      |             19.|  0.094|    1.6|  |        |                |       |       |
|        |                |       |       |  |        |                |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity      1.0348 @  15. C   Refractive Index     1.34050 @  25. C
PH                      6.60 @   0. C   Resistivity ohm/m    0.13000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:        17036.        Calculated TDS :          48227.

Sample appearance:

APPEARANCE: MUD SETTLED ON BOTTOM. NACL EQUIV 48223

Remarks:

Fe TRACE
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                    | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      73606    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):  -1144306

CHEMICAL & GEOLOGICAL LAB LTD                    Lab. Sample ID. E81-2096-1

Well identifier  Well name                                KB elev. Gr. elev
0495043611000    COLGAS DOME PEMBINA 11-36-49-4             814.40    810.70

Interval Sampled from:    1616.00   to:    1623.00 meters KB

Formation Sampled: OST

Sample produced by: DST #    1                 Sampling point:TOP OF TOOL
  DST Recovery
        18.00 M    MUD-CUT WATER
 Date:   Sampled:  1981/05/25  Received: 1981/06/01  Analyzed: 1981/06/12

               CATIONS                                ANIONS
|-------------------------------------|  |-------------------------------------|
| ION  |       mg/l     | %MEQ  | MEQ/L |  | ION  |       mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na    |          1867.| 48.481|   81.2|  |Cl    |          1780.| 29.973|   50.2|
|K     |            24.|  0.366|    0.6|  |HCO3  |          1281.| 12.533|   21.0|
|Ca    |            29.|  0.864|    1.4|  |SO4   |           247.|  3.070|    5.1|
|Mg    |             6.|  0.295|    0.5|  |CO3   |           222.|  4.417|    7.4|
|      |               |       |       |  |      |               |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity       1.0030 @  25. C   Refractive Index     1.33370 @  25. C
PH                       8.90 @  23. C   Resistivity ohm/m    1.30000 @  25. C
Hydrogen Sulfide Description:
Organics Description           :
Calculated sodium:          1881.        Calculated TDS :           4795.
TDS by Evapor. @ 110 C:          5105.   TDS at Ignition :               4595.

Sample appearance:

ORGANICS:PRESENT. THE SAMPLE CONSISTED OF VERY MUDDY WATER WITH A TRACE OF HYD
ROCARBON.

Remarks:

Fe TRACE [E81-2096-3]:DOWN HOLE SAMPLER|A LYNES DOWN HOLE SAMPLER WAS RECEIVED
 AT ATMOSPHERIC PRESSURE|IT CONTAINED 30 ML. OF MUD ONLY, INSUFFICIENT FOR ANA
LYSIS.
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                    | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      73666    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):  -1545304

CORE LABORATORIES CANADA LT.                      Lab. Sample ID.'C84-5196-4

Well identifier  Well name                                KB elev. Gr. elev
0495051416020    PROPHET ET AL PEMBINA 16-14-49-5           799.60    795.60

Interval Sampled from:    1739.00   to:    1746.00 meters KB

Formation Sampled: MISS SYS

Sample produced by: DST #    1                 Sampling point:DOWN HOLE SAMPLE
  DST Recovery
        58.00 M   CLEAN OIL
       258.00 M   OIL- AND GAS-CUT SALT WATER
 Date:   Sampled:  1984/06/08  Received: 1984/06/18  Analyzed: 1984/06/21

               CATIONS                                ANIONS
|-------------------------------------|  |-------------------------------------|
| ION  |     ` mg/l     | %MEQ  | MEQ/L |  | ION  |       mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na    |         33900.| 41.029| 1474.6|  |Cl    |         63000.| 49.444| 1777.0|
|K     |           813.|  0.579|   20.8|  |HCO3  |           944.|  0.430|   15.5|
|Ca    |          4084.|  5.670|  203.8|  |SO4   |           689.|  0.399|   14.3|
|Mg    |          1069.|  2.448|   88.0|  |      |               |       |       |
|      |               |       |       |  |      |               |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity       1.0680 @  25. C   Refractive Index     1.34950 @  25. C
PH                       7.20 @  25. C   Resistivity ohm/m    0.07900 @  25. C
Hydrogen Sulfide Description:
Organics Description           :
Calculated sodium:         34835.        Calculated TDS :         104141.
TDS by Evapor. @ 110 C:        116200.   TDS at Ignition :             101700.

Sample appearance:

A LYNES UNITED DOWNHOLE SAMPLER 214.WAS REC'D UNDER 689 KPA PRESSURE.RECOVERED
 FROM THE CHAMBER WAS GAS AND 1.9 L OF OIL STAINED MUDDY SALT WATER.

Remarks:

Fe PRESENT
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 73666 Chemistry number: 3
AGSWDB Hard copy number (HRDCPNO): -1545306

CORE LABORATORIES CANADA LT. Lab. Sample ID. E84-5197-5

Well identifier	Well name	KB elev.	Gr. elev
0495051416020	PROPHET ET AL PEMBINA 16-14-49-5	799.60	795.60

Interval Sampled from: 1731.00 to: 1738.00 meters KB

Formation Sampled: NORD

Sample produced by: DST # 3 Sampling point:DOWN HOLE SAMPLE
DST Recovery
138.00 M CLEAN OIL
380.00 M OIL-CUT SALT WATER
Date: Sampled: 1984/06/09 Received: 1984/06/10 Analyzed: 1984/06/25

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	32450.	42.484	1411.5
K	640.	0.493	16.4
Ca	3275.	4.919	163.4
Mg	744.	1.843	61.2

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	58000.	49.240	1636.0
HCO3	1010.	0.498	16.6
SO4	835.	0.523	17.4

Specific gravity 1.0600 @ 25. C
PH 6.90 @ 26. C
Refractive Index 1.34940 @ 25. C
Resistivity ohm/m 0.08400 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 33230.
Calculated TDS : 96580.
TDS by Evapor. @ 110 C: 106400.
TDS at Ignition : 94480.

Sample appearance:

LYNES UNITED SERVICES LTD.DOWNHOLE SAMPLER 56 RECEVIED UNDER 3792 KPA.RECOVERED FROM THE CHAMBER WAS GAS AND 2.5 L.OF OIL AND WATER.(13% OIL.).

Remarks:

Fe MUCH

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 73666 Chemistry number: 5
AGSWDB Hard copy number (HRDCPNO): -1545308

CORE LABORATORIES CANADA LT. Lab. Sample ID. E84-5198-1

Well identifier	Well name	KB elev.	Gr. elev
0495051416020	PROPHET ET AL PEMBINA 16-14-49-5	799.60	795.60

Interval Sampled from: 1705.00 to: 1712.00 meters KB

Formation Sampled: MISS SYS

Sample produced by: DST # 5 Sampling point:TOP
DST Recovery
143.00 M MUD
199.00 M GAS-CUT SALT WATER
Date: Sampled: 1984/06/10 Received: 1984/06/10 Analyzed: 1984/06/15

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	42090.	37.752	1830.8
K	724.	0.382	18.5
Ca	7988.	8.219	398.6
Mg	1944.	3.299	160.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	86000.	50.019	2425.7
HCO3	549.	0.186	9.0
SO4	335.	0.144	7.0

Specific gravity 1.0860 @ 25. C
PH 7.20 @ 26. C
Refractive Index 1.35670 @ 25. C
Resistivity ohm/m 0.06700 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 43299.
Calculated TDS : 139836.
TDS by Evapor. @ 110 C: 161600.
TDS at Ignition : 133700.

Sample appearance:

THE SAMPLE CONSISTED OF SLIGHTLY MUDDY SALT WATER.

Remarks:

Fe PRESENT [E84-05198-2]:SAMPLED FROM MIDDLE.|RESISTIVITY:0.071 OHM/METERS @25 C.|SLIGHTLY MUDDY WATER.|H2S.PRESENT.[E84-05198-3]:SAMPLED FROM BOTTOM|RESISTIVITY:0.070 OHM/METERS @25C.|SLIGHTLY MUDDY WATER.|H2S.PRESENT.|[E84-05198-4]:SAMPLED FROM DOWNH OLE SAMPLER.|RES.:0.126 OHM/METERS @25C.|LYNES UNITED SERVICES LTD.|DOWNHOLE SAMPLER 65 RECEIVED UNDER ATMOSPHERIC PRESSURE AND CONTAINED 600 ML OF MUD ONLY.

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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     73715   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):   -293409

CHEMICAL & GEOLOGICAL LAB LTD                  Lab. Sample ID. 9758

Well identifier  Well name                                KB elev. Gr. elev
0495053108000    WHITE ROSE-SUPERTEST W. ALSIKE 8-31         780.30    776.60

Interval Sampled from:   1940.66  to:   1948.59 meters KB

Formation Sampled: WAB

Sample produced by: DST #    3                 Sampling point:
 Date:   Sampled:  1957/04/30                         Analyzed: 1957/05/02

                CATIONS                                     ANIONS
|-----------------------------------|     |------------------------------------|
|  ION  |     mg/l      | %MEQ | MEQ/L|     |  ION  |      mg/l      | %MEQ | MEQ/L|
|-----------------------------------|     |------------------------------------|
|Na     |        45344.| 35.409| 1972.4|     |Cl     |         98016.| 49.633| 2764.7|
|Ca     |        12958.| 11.608|  646.6|     |HCO3   |           680.|  0.200|   11.1|
|Mg     |         2016.|  2.978|  165.9|     |SO4    |           461.|  0.172|    9.6|
|       |              |       |       |     |       |              |       |       |
|-----------------------------------|     |------------------------------------|

Specific gravity       1.1100 @    0. C
PH                       7.20 @    0. C   Resistivity ohm/m    0.07200 @  20. C
Calculated sodium:        45364.          Calculated TDS :        159149.
TDS by Evapor. @ 110 C:        161200.    TDS at Ignition :             147100.
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     78124   Chemistry number:    2
AGSWDB Hard copy number   (HRDCPNO):     39591

CHEMICAL & GEOLOGICAL LAB LTD                  Lab. Sample ID. C81-7501-2

Well identifier  Well name                                KB elev. Gr. elev
0505030210000    COLGAS GENESEE 10-2-50-3                    799.80    796.10

Interval Sampled from:   1564.00  to:   1571.00 meters KB

Formation Sampled: OSTRACOD

Sample produced by: DST #    3                 Sampling point:BOTTOM
  DST Recovery
         9.00 M   MUD
 Date:   Sampled:  1981/03/08  Received: 1981/03/12  Analyzed: 1981/03/24

                CATIONS                                     ANIONS
|-----------------------------------|     |------------------------------------|
|  ION  |     mg/l      | %MEQ | MEQ/L|     |  ION  |      mg/l      | %MEQ | MEQ/L|
|-----------------------------------|     |------------------------------------|
|Na     |         1425.| 53.566|   62.0|     |Cl     |           675.| 16.453|   19.0|
|K      |           16.|  0.354|    0.4|     |HCO3   |          1440.| 20.395|   23.6|
|Ca     |           24.|  1.035|    1.2|     |SO4    |           150.|  2.699|    3.1|
|Mg     |           19.|  1.351|    1.6|     |CO3    |           144.|  4.147|    4.8|
|       |              |       |       |     |       |              |       |       |
|-----------------------------------|     |------------------------------------|

Specific gravity       1.0020 @   25. C   Refractive Index     1.33340 @  25. C
PH                       9.00 @   23. C   Resistivity ohm/m    1.98000 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:         1099.          Calculated TDS :          2819.
TDS by Evapor. @ 110 C:          5336.    TDS at Ignition :               3204.

Sample appearance:

CLEAR, COLORLESS FILTRATE REC'D FROM MUD.

Remarks:

FE MUCH. C81-7501-3 DHS #81 DHS HAD AN OPENING PRESSURE OF 0 KPA @ 20 C. IT CO
NTAINED NO FLUID.              ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
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                | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78124    Chemistry number:    3
AGSWDB Hard copy number    (HRDCPNO):     39592

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. C81-7502-3

Well identifier  Well name                                KB elev. Gr. elev
0505030210000    COLGAS GENESEE 10-2-50-3                   799.80    796.10

Interval Sampled from:    1548.00  to:    1558.00 meters KB

Formation Sampled: GLAUCONITIC

Sample produced by: DST #    4                   Sampling point:BOTTOM
  DST Recovery
        38.00 M   OIL-CUT MUD
 Date:   Sampled:  1981/03/09  Received: 1981/03/12  Analyzed: 1981/03/30

                CATIONS                                   ANIONS
|------------------------------------|   |------------------------------------|
|  ION  |       mg/l      | %MEQ  | MEQ/L |   |  ION  |       mg/l      | %MEQ  | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na     |           1195.| 54.747|   52.0|   |Cl     |            650.| 19.310|   18.3|
|K      |              4.|  0.108|    0.1|   |HCO3   |           1141.| 19.695|   18.7|
|Ca     |             16.|  0.841|    0.8|   |SO4    |             49.|  1.075|    1.0|
|Mg     |              5.|  0.433|    0.4|   |CO3    |            108.|  3.791|    3.6|
|       |                |       |       |   |       |                |       |       |
|------------------------------------|   |------------------------------------|

Specific gravity       1.0000 @  25. C   Refractive Index      1.33320 @  25. C
PH                       9.00 @  24. C   Resistivity ohm/m     2.16000 @  25. C
Hydrogen Sulfide Description:
Organics Description         :
Calculated sodium:          930.         Calculated TDS :           2319.
TDS by Evapor. @ 110 C:          4220.   TDS at Ignition :               2376.

Sample appearance:

PALE YELLOW FILTRATE RECOVERED FROM OIL FLECKED WATERY MUD.

Remarks:

FE PRESENT. C81-7502-1 TOP RES: 2.36 OHM/M @25C PALE YELLOW FILTRATE RECOVERED
 FROM OIL FLECKED MUD. -2 MIDDLE RES: 2.34 OHM/M @25C PALE YELLOW FILTRATE REC
OVERED FROM MUD WITH TRACE HYDROCARBONS. 4 DHS #176 NO ANALYSIS.
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                | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78129    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     39596

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. C81-8438-4

Well identifier  Well name                                KB elev. Gr. elev
0505030601000    COLGAS DOME GENESEE 1-6-50-3               787.30    783.60

Interval Sampled from:    1607.00  to:    1616.00 meters KB

Formation Sampled: BANFF

Sample produced by: DST #    2                   Sampling point:BOTTOM
  DST Recovery
        25.00 M   MUD
        70.00 M   GAS- AND OIL-CUT MUD
        55.00 M   OIL-CUT SALT WATER
 Date:   Sampled:  1981/05/08  Received: 1981/05/12  Analyzed: 1981/05/29

                CATIONS                                   ANIONS
|------------------------------------|   |------------------------------------|
|  ION  |       mg/l      | %MEQ  | MEQ/L |   |  ION  |       mg/l      | %MEQ  | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na     |          25090.| 40.346| 1091.4|   |Cl     |          50300.| 52.451| 1418.8|
|K      |            516.|  0.488|   13.2|   |HCO3   |            720.|  0.436|   11.8|
|Ca     |           1942.|  3.583|   96.9|   |SO4    |            551.|  0.424|   11.5|
|Mg     |            747.|  2.272|   61.5|   |       |                |       |       |
|       |                |       |       |   |       |                |       |       |
|------------------------------------|   |------------------------------------|

Specific gravity       1.0560 @  25. C   Refractive Index      1.34740 @  25. C
PH                       7.40 @  23. C   Resistivity ohm/m     0.08600 @  25. C
Hydrogen Sulfide Description:
Organics Description         :
Calculated sodium:        29515.         Calculated TDS :          83409.
TDS by Evapor. @ 110 C:        113900.   TDS at Ignition :              83620.

Sample appearance:

CLEAR COLORLESS FILTRAT WITH APP. 30% SEDIMENT AND TRACE HYDROCARBONS.

Remarks:

FE MUCH. C81-8438-2 TOP RES: .289 OHM/M @25C CLEAR COLORLESS FILTRATE RECOVER-
 ED FROM MUD. -3 MIDDLE RES: .102 OHM/M @25C CLEAR COLORLESS FILTRATE RECOVERE
D FROM WATER. -4 DHS RES: .089 OHM/M @25C CLEAR COLORLESS FILTRATE RECOVERED F
ROM OIL FLECKED WATERY MUD.
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78134    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     39600

CHEMEX LABS (ALBERTA) LTD.                        Lab. Sample ID. 82-42-2-5X-3832

Well identifier  Well name                                    KB elev. Gr. elev
0505030706000    PCP GENESEE 6-7-50-3                            766.80    763.00

Interval Sampled from:   1584.50   to:   1588.00 meters KB

Formation Sampled: OST 3120

Sample produced by:                               Sampling point:SEPARATOR
 Date:   Sampled:  1983/03/14  Received: 1983/03/16  Analyzed: 1983/03/17

                CATIONS                                   ANIONS
|------------------------------------|   |------------------------------------|
|  ION  |      mg/l      | %MEQ  | MEQ/L |   |  ION  |      mg/l      | %MEQ  | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na     |         28800.| 31.435| 1252.7|   |Cl     |         72700.| 51.456| 2050.6|
|K      |           500.|  0.321|   12.8|   |HCO3   |           771.|  0.317|   12.6|
|Ca     |          8000.| 10.017|  399.2|   |SO4    |           393.|  0.205|    8.2|
|Mg     |          3000.|  6.195|  246.9|   |       |               |       |       |
|Fe     |            60.|  0.054|    2.1|   |       |               |       |       |
|------------------------------------|   |------------------------------------|

Specific gravity       1.0900 @  15. C   Refractive Index       1.35100 @  25. C
PH                       7.35 @  25. C   Resistivity ohm/m      0.09400 @  25. C
Calculated sodium:       32775.          Calculated TDS :          117247.
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78139    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     39611

CHEMICAL & GEOLOGICAL LAB LTD                     Lab. Sample ID.:E83-10726-4

Well identifier  Well name                                    KB elev. Gr. elev
0505031806000    COLGAS DOME GENESEE 6-18-50-3                   738.50    734.80

Interval Sampled from:   1559.50   to:   1564.00 meters KB

Formation Sampled: ELLERSLIE

Sample produced by: DST #    3                    Sampling point:TOP OF TOOL
  DST Recovery
       163.00 M   GAS- AND OIL-CUT MUD
 Date:   Sampled:  1983/02/28  Received: 1983/03/02  Analyzed: 1983/03/10

                CATIONS                                   ANIONS
|------------------------------------|   |------------------------------------|
|  ION  |      mg/l      | %MEQ  | MEQ/L |   |  ION  |      mg/l      | %MEQ  | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na     |          4810.| 48.827|  209.2|   |Cl     |          6400.| 42.128|  180.5|
|K      |            74.|  0.442|    1.9|   |HCO3   |          1275.|  4.876|   20.9|
|Ca     |            80.|  0.932|    4.0|   |SO4    |           387.|  1.880|    8.1|
|Mg     |            46.|  0.883|    3.8|   |CO3    |             4.|  0.031|    0.1|
|       |               |       |       |   |       |               |       |       |
|------------------------------------|   |------------------------------------|

Specific gravity       1.0090 @  25. C   Refractive Index       1.33510 @  25. C
PH                       8.70 @  23. C   Resistivity ohm/m      0.47200 @  25. C
Hydrogen Sulfide Description:
Organics Description           :
Calculated sodium:         4640.         Calculated TDS :          12184.
TDS by Evapor. @ 110 C:        13280.    TDS at Ignition :             10500.

Sample appearance:

SLIGHTLY SALTY WATER EXTRACTED FROM OIL FLECKED MUD.

Remarks:

FE PRESENT. E83-10726-1 152M ABOVE TOOL RES OF FILT: 1.80 OHM/M @25C MUD. -2 7
6M ABOVE TOOL RES OF FILT: 1.48 OHM/M @25C MUD. -3 19M ABOVE TOOL RES OF FILT:
 .594 OHM/M @25C OIL FLECKED MUD. -5 DHS RES OF FILT: .502 OHM/M @25C QUINN DH
S REC'D @ATM PRESSURE, 1.4L OF OIL FLECKED MUD.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78247 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 39773

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E85-13930

Well identifier	Well name	KB elev.	Gr. elev
0505053608000	ANDEX ET AL HIGHVALE 8-36-50-5	760.60	755.80

Interval Sampled from: 1602.00 to: 1606.00 meters KB

Formation Sampled: NORDEGG

Sample produced by: Sampling point:TEST SEPARATOR
Date: Sampled: 1985/04/01 Received: 1985/04/04 Analyzed: 1985/04/19

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	33570.	39.389	1460.2
K	795.	0.548	20.3
Ca	4653.	6.263	232.2
Mg	1351.	2.999	111.2

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	66100.	50.292	1864.4
HCO3	466.	0.206	7.6
SO4	539.	0.303	11.2

Other Determinations

Parameter	mg/l
boron	19.
strontium	354.

Specific gravity 1.0700 @ 25. C Refractive Index 1.35150 @ 25. C
PH 7.00 @ 21. C Resistivity ohm/m 0.07700 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 35407. Calculated TDS : 108280.
TDS by Evapor. @ 110 C: 121400. TDS at Ignition : 106400.

Remarks:

FE PRESENT.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78247 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): 39774

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E85-13872-4

Well identifier	Well name	KB elev.	Gr. elev
0505053608000	ANDEX ET AL HIGHVALE 8-36-50-5	760.60	755.80

Interval Sampled from: 1607.00 to: 1625.00 meters KB

Formation Sampled: BF

Sample produced by: DST # 1 Sampling point:DHS
DST Recovery
9.00 M OIL-CUT MUD
129.00 M GAS- AND OIL-CUT MUD
Date: Sampled: 1985/03/19 Received: 1985/03/21 Analyzed: 1985/04/09

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	7100.	45.236	308.8
K	98.	0.367	2.5
Ca	238.	1.740	11.9
Mg	162.	1.953	13.3

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	11090.	45.819	312.8
HCO3	686.	1.647	11.2
SO4	1062.	3.239	22.1

Specific gravity 1.0100 @ 25. C Refractive Index 1.33600 @ 25. C
PH 8.00 @ 23. C Resistivity ohm/m 0.28300 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 7379. Calculated TDS : 20269.
TDS by Evapor. @ 110 C: 20160. TDS at Ignition : 18400.

Sample appearance:

LYNES DHS REC'D @ATM PRESSURE, 400MLS SLIGHTLY SALTY OIL CUT MUDDY WATER (8% OIL).

Remarks:

FE TRACE. E85-13872-1 TOP RES: 1.03 OHM/M @25C MUD, TRACE HYDROCARBON. -2 MIDDLE RES: .341 OHM/M @25C OIL CUT MUDDY WATER (16% OIL). -3 BOTTOM RES: .312 OHM/M @25C OIL CUT MUDDY WATER (10% OIL).

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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     78240    Chemistry number:    2
AGSWDB Hard copy number    (HRDCPNO):    39764

CHEMICAL & GEOLOGICAL LAB LTD                  Lab. Sample ID. E81-17778-3

Well identifier  Well name                              KB elev. Gr. elev
0505052403000    ANDEX ET AL HIGHVALE 3-24-50-5            695.80    691.70

Interval Sampled from:   1573.00  to:   1580.00 meters KB

Formation Sampled: BANFF

Sample produced by: DST #    1                 Sampling point:DHS
  DST Recovery
        38.00 M   OIL-CUT MUD
 Date:   Sampled:  1981/02/26  Received: 1981/03/04  Analyzed: 1981/03/17

                CATIONS                                    ANIONS
|-------------------------------------|   |-------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |   |  ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na      |        3826.| 46.954|  166.4|   |Cl      |        5520.| 43.929|  155.7|
|K       |          40.|  0.289|    1.0|   |HCO3    |         791.|  3.658|   13.0|
|Ca      |         108.|  1.521|    5.4|   |SO4     |         412.|  2.420|    8.6|
|Mg      |          53.|  1.230|    4.4|   |        |             |       |       |
|        |             |       |       |   |        |             |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity       1.0040 @  25. C   Refractive Index     1.33500 @  25. C
PH                       7.50 @  22. C   Resistivity ohm/m    0.58900 @  25. C
Hydrogen Sulfide Description:
Organics Description         :
Calculated sodium:          3851.        Calculated TDS :            10333.
TDS by Evapor. @ 110 C:          10720.  TDS at Ignition :                9040.

Sample appearance:

QUINN DHS REC'D @620 KPA. GAS AND 3.4L OF OIL CUT MUD.

Remarks:

FE NIL. E81-17778-1 OM RES: 1.50 OHM/M @25C OIL FLECKED MUD.
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     78243    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):    39769

CHEMICAL & GEOLOGICAL LAB LTD                  Lab. Sample ID. E85-15363-3

Well identifier  Well name                              KB elev. Gr. elev
0505052516000    ANDEX ET AL HIGHVALE 16-25-50-5           780.50    775.70

Interval Sampled from:   1624.00  to:   1645.00 meters KB

Formation Sampled: NORDEGG

Sample produced by: DST #    1                 Sampling point:BOTTOM
  DST Recovery
       361.00 M   CLEAN OIL
        10.00 M   OIL-CUT MUD
 Date:   Sampled:  1985/05/15  Received: 1985/05/17  Analyzed: 1985/05/24

                CATIONS                                    ANIONS
|-------------------------------------|   |-------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |   |  ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na      |        4360.| 47.150|  189.6|   |Cl      |        5810.| 40.743|  163.9|
|K       |          48.|  0.305|    1.2|   |HCO3    |        1527.|  6.222|   25.0|
|Ca      |          80.|  0.992|    4.0|   |SO4     |         732.|  3.789|   15.2|
|Mg      |          39.|  0.798|    3.2|   |        |             |       |       |
|        |             |       |       |   |        |             |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity       1.0080 @  25. C   Refractive Index     1.33470 @  25. C
PH                       7.90 @  26. C   Resistivity ohm/m    0.50400 @  25. C
Hydrogen Sulfide Description:
Organics Description         :
Calculated sodium:          4528.        Calculated TDS :            11940.
TDS by Evapor. @ 110 C:          11870.  TDS at Ignition :                9960.

Sample appearance:

CLEAR COLORLESS SLIGHTLY SALTY WATER RECOVERED FROM OIL CUT MUD (36% OIL).

Remarks:

FE TRACE.         ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
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                    | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78152    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     39628

CHEMICAL & GEOLOGICAL LAB LTD                    Lab. Sample ID. C82-13309

Well identifier  Well name                                  KB elev. Gr. elev
0505040208000    COLGAS ET AL PEMBINA 8-2-50-4                 803.60    799.90

Interval Sampled from:    1636.00  to:    1646.00 meters KB

Formation Sampled: BF

Sample produced by:                              Sampling point:STOCK TANK
 Date:    Sampled:  1982/01/25  Received: 1982/01/25  Analyzed: 1982/02/15

                CATIONS                                    ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION   |      mg/l     | %MEQ  | MEQ/L |  |  ION   |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na      |        26790.| 44.122| 1165.3|  |Cl      |        46900.| 50.089| 1322.9|
|K       |          704.|  0.682|   18.0|  |HCO3    |          986.|  0.612|   16.2|
|Ca      |         1413.|  2.670|   70.5|  |SO4     |          700.|  0.552|   14.6|
|Mg      |          409.|  1.274|   33.7|  |        |              |       |       |
|        |              |       |       |  |        |              |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity       1.0530 @  25. C   Refractive Index      1.34590 @  25. C
PH                       7.90 @  24. C   Resistivity ohm/m     0.10100 @  25. C
Hydrogen Sulfide Description:
Organics Description         :
Calculated sodium:        28727.         Calculated TDS :           78634.
TDS by Evapor. @ 110 C:          80060.  TDS at Ignition :                74930.

Sample appearance:

CLEAR COLORLESS FILTRATE WITH TRACE SEDIMENT.

Remarks:

FE TRACE.
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                    | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78152    Chemistry number:    2
AGSWDB Hard copy number    (HRDCPNO):     39629

CHEMICAL & GEOLOGICAL LAB LTD                    Lab. Sample ID. E81-7919-2

Well identifier  Well name                                  KB elev. Gr. elev
0505040208000    COLGAS ET AL PEMBINA 8-2-50-4                 803.60    799.90

Interval Sampled from:    1633.00  to:    1647.00 meters KB

Formation Sampled: BANFF

Sample produced by: DST #    2                   Sampling point:MIDDLE
  DST Recovery
        35.00 M   CLEAN OIL
        40.00 M   GAS- AND OIL-CUT MUD
 Date:    Sampled:  1981/10/11  Received: 1981/10/13  Analyzed: 1981/11/02

                CATIONS                                    ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION   |      mg/l     | %MEQ  | MEQ/L |  |  ION   |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na      |         4486.| 47.134|  195.1|  |Cl      |         6570.| 44.764|  185.3|
|K       |          125.|  0.772|    3.2|  |HCO3    |          622.|  2.462|   10.2|
|Ca      |          148.|  1.784|    7.4|  |SO4     |          477.|  2.399|    9.9|
|Mg      |           15.|  0.298|    1.2|  |CO3     |           48.|  0.386|    1.6|
|        |              |       |       |  |        |              |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity       1.0080 @  25. C   Refractive Index      1.33490 @  25. C
PH                       8.50 @  22. C   Resistivity ohm/m     0.47700 @  25. C
Hydrogen Sulfide Description:
Organics Description         :
Calculated sodium:         4562.         Calculated TDS :           12126.
TDS by Evapor. @ 110 C:          12180.  TDS at Ignition :                11020.

Sample appearance:

SLIGHTLY SALTY WATER EXTRACTED FROM SLIGHTLY OIL CUT MUD.

Remarks:

FE PRESENT. E81-7919-1 TOP RES OF FILT: .476 OHM/M @25C SLIGHTLY OIL CUT MUD.
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78147    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     39625

CHEMICAL & GEOLOGICAL LAB LTD                    Lab. Sample ID. E82-13342-3

Well identifier  Well name                                 KB elev. Gr. elev
0505040106000    PCP PEMBINA 6-1-50-4                        790.40    785.70

Interval Sampled from:    1614.50  to:    1647.00 meters KB

Formation Sampled: GLC

Sample produced by: DST #     1                  Sampling point:28M ABOVE TOOL
  DST Recovery
        28.00 M    CLEAN OIL
       140.00 M    GAS- AND OIL-CUT MUD
 Date:    Sampled:  1982/03/02  Received: 1982/03/05  Analyzed: 1982/03/12

                 CATIONS                                  ANIONS
|-----------------------------------------|  |-----------------------------------------|
|  ION  |      mg/l      | %MEQ  | MEQ/L  |  |  ION  |      mg/l      | %MEQ  | MEQ/L  |
|-----------------------------------------|  |-----------------------------------------|
|Na     |          1369.| 31.111|    59.5|  |Cl     |          1350.| 19.894|    38.1|
|K      |            64.|  0.855|     1.6|  |HCO3   |          3228.| 27.640|    52.9|
|Ca     |           537.| 14.000|    26.8|  |SO4    |           226.|  2.458|     4.7|
|Mg     |            94.|  4.041|     7.7|  |       |               |       |        |
|       |               |       |        |  |       |               |       |        |
|-----------------------------------------|  |-----------------------------------------|

Specific gravity        1.0040 @   25. C   Refractive Index       1.33700 @   25. C
PH                        8.00 @   23. C   Resistivity ohm/m      2.08000 @   25. C
Hydrogen Sulfide Description:
Organics Description           :
Calculated sodium:          1406.          Calculated TDS :            5200.
TDS by Evapor. @ 110 C:          11470.    TDS at Ignition :                3080.

Sample appearance:

INHIBITOR CONTAMINATED MUDDY WATER.

Remarks:

FE PRESENT. E82-13342-1 168M RES: 2.76 OHM/M @25C (SAME AS ABOVE). E82-13342-2
 98M RES: 2.66 OHM/M 225C (SAME AS ABOVE).
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78149    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     39626

CHEMICAL & GEOLOGICAL LAB LTD                    Lab. Sample ID. C82-11979-4

Well identifier  Well name                                 KB elev. Gr. elev
0505040108020    PCP PEMBINA A8-1-50-4                       789.60    784.90

Interval Sampled from:    1610.00  to:    1620.00 meters KB

Formation Sampled: BF

Sample produced by: DST #     4                  Sampling point:DHS #78
  DST Recovery
       111.00 M    GAS- AND OIL-CUT MUD
 Date:    Sampled:  1981/11/22  Received: 1981/11/24  Analyzed: 1982/01/12

                 CATIONS                                  ANIONS
|-----------------------------------------|  |-----------------------------------------|
|  ION  |    . mg/l      | %MEQ  | MEQ/L  |  |  ION  |      mg/l      | %MEQ  | MEQ/L  |
|-----------------------------------------|  |-----------------------------------------|
|Na     |          2090.| 47.344|    90.9|  |Cl     |          2050.| 30.113|    57.8|
|K      |            20.|  0.266|     0.5|  |HCO3   |          1525.| 13.016|    25.0|
|Ca     |            20.|  0.520|     1.0|  |SO4    |           543.|  5.888|    11.3|
|Mg     |            18.|  0.771|     1.5|  |CO3    |           120.|  2.083|     4.0|
|       |               |       |        |  |       |               |       |        |
|-----------------------------------------|  |-----------------------------------------|

Specific gravity        1.0040 @   25. C   Refractive Index       1.33360 @   25. C
PH                        8.90 @   25. C   Resistivity ohm/m      1.45000 @   25. C
Hydrogen Sulfide Description:
Organics Description           :
Calculated sodium:          2199.          Calculated TDS :            5700.
TDS by Evapor. @ 110 C:           6527.    TDS at Ignition :                4367.

Sample appearance:

PALE YELLOW FILTRATE RECOVERED FROM MUD WITH TRACE HYDROCARBONS. DHS REC'D @0
KPA @23C, 1100MLS FLECKED OIL.

Remarks:

FE PRESENT. C82-11979-1 TOP RES: 2.24 OHMM @25C PALE YELLOW FILTRATE RECOVERED
 FROM MUD. -2 MIDDLE RES: 1.90 OHM/M @25C PALE YELLOW FILTRATE RECOVERED FROM
MUD WITH TRACE HYDROCARBONS. -3 BOTTOM RES: 1.46 OHM/M @25C (SAME AS 2).
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78157 Chemistry number: 6
AGSWDB Hard copy number (HRDCPNO): 39644

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E81-8729-3

Well identifier	Well name	KB elev.	Gr. elev
0505040316000	ESSO PCP PEMBINA 16-3-50-4	781.30	777.30

Interval Sampled from: 1585.00 to: 1595.00 meters KB

Formation Sampled: GLAUCONITE

Sample produced by: DST # 6 Sampling point:COLUMN #3
DST Recovery
350.00 M MUD-CUT WATER
Date: Sampled: 1981/11/01 Received: 1981/11/05 Analyzed: 1981/11/24

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	18904.	46.955	822.3
K	220.	0.321	5.6
Ca	721.	2.054	36.0
Mg	141.	0.663	11.6

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	30600.	49.287	863.1
HCO3	602.	0.563	9.9
SO4	132.	0.157	2.7

Specific gravity 1.0330 @ 25. C
PH 7.90 @ 22. C
Refractive Index 1.34150 @ 25. C
Resistivity ohm/m 0.14300 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 19041.
Calculated TDS : 50931.
TDS by Evapor. @ 110 C: 55340.
TDS at Ignition : 46180.

Sample appearance:

MUDDY SALT WATER.

Remarks:

FE NIL. E81-8729-1 COLUMN #1 RES: .187 OHM/M @25C MUD. -2 COLUMN #2 RES: .309 OHM/M @25C MUD.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78160 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 39652

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID.,E79-17445

Well identifier	Well name	KB elev.	Gr. elev
0505040816000	ANDEX ET PEMBINA 16-8-50-4	755.20	751.10

Interval Sampled from: 1598.00 to: 1620.00 meters KB

Formation Sampled: GLS SS.

Sample produced by: DST # 1 Sampling point:DSH
DST Recovery
22.00 M MUD
38.00 M GAS- AND OIL-CUT MUD
Date: Sampled: 1979/11/18 Received: 1979/11/28 Analyzed: 1979/12/18

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	4030.	47.685	175.3
K	58.	0.403	1.5
Ca	65.	0.882	3.2
Mg	46.	1.030	3.8

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	5380.	41.280	151.8
HCO3	898.	4.003	14.7
SO4	687.	3.891	14.3
CO3	91.	0.825	3.0

Specific gravity 1.0080 @ 25. C
PH 8.40 @ 20. C
Refractive Index 1.33460 @ 25. C
Resistivity ohm/m 0.56600 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 4064.
Calculated TDS : 10775.
TDS by Evapor. @ 110 C: 12380.
TDS at Ignition : 10550.

Sample appearance:

THE ANALYSIS DETERMINED ON SL. SALTY WATER EXTRACTED FROM OIL-FLECKED MUD.

Remarks:

FE NIL.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78156 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 39637

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. C82-14598-3

Well identifier	Well name	KB elev.	Gr. elev
0505040216000	COLGAS ET AL PEMBINA 16-2-50-4	794.80	791.10

Interval Sampled from: 1623.00 to: 1630.00 meters KB

Formation Sampled: OSTRACOD

Sample produced by: DST # 1 Sampling point:BOTTOM
DST Recovery
95.00 M MUD
760.00 M SALT WATER
Date: Sampled: 1982/03/30 Received: 1982/03/31 Analyzed: 1982/04/27

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	21620.	42.602	940.4
K	188.	0.218	4.8
Ca	953.	2.154	47.6
Mg	345.	1.286	28.4

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	41400.	52.900	1167.7
HCO3	342.	0.254	5.6
SO4	16.	0.015	0.3
CO3	378.	0.571	12.6

Specific gravity 1.0480 @ 25. C
PH 8.50 @ 23. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 25529.
TDS by Evapor. @ 110 C: 65150.

Refractive Index 1.34270 @ 25. C
Resistivity ohm/m 0.11500 @ 25. C
Calculated TDS : 68789.
TDS at Ignition : 61460.

Sample appearance:

CLEAR COLORLESS FILTRATE RECOVERED FROM MUDDY WATER.

Remarks:

FE PRESENT. C82-14598-1 TOP RES: 1.29 OHM/M @25C (SAME AS ABOVE). -2 MIDDLE RES: .118 OHM/M @25C (SAME AS ABOVE). -4 DHS #197 RES: .118 OHM/M @25C CLEAR COLORLESS FILTRATE WITH TRACE SEDIMENT.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78157 Chemistry number: 5
AGSWDB Hard copy number (HRDCPNO): 39643

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E81-8617

Well identifier	Well name	KB elev.	Gr. elev
0505040316000	ESSO PCP PEMBINA 16-3-50-4	781.30	777.30

Interval Sampled from: 1585.00 to: 1595.00 meters KB

Formation Sampled: GLAUCONITE

Sample produced by: DST # 6 Sampling point:
DST Recovery
350.00 M MUD-CUT WATER
Date: Sampled: 1981/11/01 Received: 1981/11/04 Analyzed: 1981/11/20

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	15000.	46.367	652.5
K	213.	0.387	5.4
Ca	521.	1.848	26.0
Mg	238.	1.392	19.6

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	24600.	49.311	693.9
HCO3	427.	0.497	7.0
SO4	134.	0.198	2.8

Specific gravity 1.0280 @ 25. C
PH 8.00 @ 21. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 15131.
TDS by Evapor. @ 110 C: 41060.

Refractive Index 1.34030 @ 25. C
Resistivity ohm/m 0.15800 @ 25. C
Calculated TDS : 40834.
TDS at Ignition : 37900.

Sample appearance:

MUDY SALT WATER RECOVERED FROM JOHNSTON DHS.

Remarks:

FE PRESENT.

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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78162    Chemistry number:     3
AGSWDB Hard copy number    (HRDCPNO):     39657

CHEMICAL & GEOLOGICAL LAB LTD                     Lab. Sample ID. F75-1207-5

Well identifier  Well name                                   KB elev. Gr. elev
0505040907000    SKELLY ET AL A1 LINDALE 7-9-50-4              773.30    769.30

Interval Sampled from:    1594.10   to:    1600.20 meters KB

Formation Sampled: MANNVILLE

Sample produced by: DST #     3                   Sampling point:TOOL
  DST Recovery
        30.50 M    MUD
       182.90 M    SALT WATER
 Date:    Sampled:   1975/08/17  Received: 1975/08/21  Analyzed: 1975/08/22

                CATIONS                                     ANIONS
|-------------------------------------|   |-------------------------------------|
|  ION   |      mg/l     | %MEQ  | MEQ/L |   |  ION   |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na      |         18703.| 47.374|  813.5|   |Cl      |         29900.| 49.112|  843.4|
|Ca      |           681.|  1.979|   34.0|   |HCO3    |           781.|  0.745|   12.8|
|Mg      |           134.|  0.642|   11.0|   |SO4     |           122.|  0.148|    2.5|
|        |               |       |       |   |        |               |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity       1.0360 @  16. C   Refractive Index     1.34180 @  25. C
PH                       7.80 @  23. C   Resistivity ohm/m    0.13400 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:        18708.         Calculated TDS :            49929.
TDS by Evapor. @ 110 C:        52360.    TDS at Ignition :               49310.

Sample appearance:

PALE YELLOW WATER WITH TRACE SEDIMENT.

Remarks:

FE PRESENT. F75-1207-1 TOP OF FLUID RES: .426 OHM/M @25C DARK RED WATER WITH 3
0% SEDIMENT. -2 270' ABOVE TOOL RES: .149 OHM/M @25C PALE YELLOW WATER WITH TR
ACE SEDIMENT. -3 90' ABOVE TOOL RES: .135 OHM/M @25C (SAME AS 2). -4 TOP OF TO
OL RES: .135 OHM/M @25C (SAME AS 2).
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78164    Chemistry number:     1
AGSWDB Hard copy number    (HRDCPNO):     39660

CHEMICAL & GEOLOGICAL LAB LTD                     Lab. Sample ID. E83-17271-2

Well identifier  Well name                                   KB elev. Gr. elev
0505041108000    ANDEX ET AL PEMBINA 8-11-50-4                 778.30    773.60

Interval Sampled from:    1562.00   to:    1567.00 meters KB

Formation Sampled: GLAUCONITE

Sample produced by: DST #     3                   Sampling point:DHS
  DST Recovery
        19.00 M    MUD
 Date:    Sampled:   1983/09/28  Received: 1983/09/30  Analyzed: 1983/10/04

                CATIONS                                     ANIONS
|-------------------------------------|   |-------------------------------------|
|  ION   |      mg/l     | %MEQ  | MEQ/L |   |  ION   |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na      |          3770.| 49.999|  164.0|   |Cl      |          4790.| 41.195|  135.1|
|K       |            25.|  0.195|    0.6|   |HCO3    |           617.|  3.083|   10.1|
|Ca      |            35.|  0.533|    1.7|   |SO4     |           691.|  4.387|   14.4|
|Mg      |             2.|  0.050|    0.2|   |CO3     |            55.|  0.559|    1.8|
|        |               |       |       |   |        |               |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity       1.0060 @  25. C   Refractive Index     1.33450 @  25. C
PH                       8.60 @  21. C   Resistivity ohm/m    0.51600 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:         3668.         Calculated TDS :             9544.
TDS by Evapor. @ 110 C:        10340.    TDS at Ignition :                8790.

Sample appearance:

LYNES DHS REC'D @ATM PRESSURE, 2L OF MUD. SLIGHTLY SALTY WATER EXRACTED FROM M
UD.

Remarks:

FE TRACE. E83-17271-1 TOP OF TOOL RES: .775 OHM/M @25C MUD.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78160 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): 39653

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E79-17100-3

Well identifier	Well name	KB elev.	Gr. elev
0505040816000	ANDEX ET PEMBINA 16-8-50-4	755.20	751.10

Interval Sampled from: 1598.00 to: 1620.00 meters KB

Formation Sampled: GLC

Sample produced by: DST # 1 Sampling point:TOP OF TOOL
DST Recovery
22.00 M MUD
38.00 M GAS- AND OIL-CUT MUD
Date: Sampled: 1979/11/18 Received: 1979/11/22 Analyzed: 1979/12/10

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	3982.	48.294	173.2
K	57.	0.406	1.5
Ca	75.	1.043	3.7
Mg	11.	0.252	0.9

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	5174.	40.691	145.9
HCO3	1042.	4.761	17.1
SO4	523.	3.036	10.9
CO3	163.	1.515	5.4

Specific gravity 1.0050 @ 25. C
PH 8.60 @ 22. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 4016.
TDS by Evapor. @ 110 C: 11780.

Refractive Index 1.33460 @ 25. C
Resistivity ohm/m 0.59600 @ 25. C
Calculated TDS : 10475.
TDS at Ignition : 8840.

Sample appearance:

SLIGHTLY SALTY WATER EXTRACTED FROM OIL FLECKED MUD.

Remarks:

FE PRESENT. E79-17100-1 TOP OF FLUID RES OF FILT: 2.28 OHM/M @25C MUD. -2 MIDDLE RES OF FILT: 1.64 OHM/M @25C OIL FLECKED MUD.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78162 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): 39656

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. F75-1189-5

Well identifier	Well name	KB elev.	Gr. elev
0505040907000	SKELLY ET AL A1 LINDALE 7-9-50-4	773.30	769.30

Interval Sampled from: 1585.57 to: 1605.08 meters KB

Formation Sampled: MANNVILLE

Sample produced by: DST # 2 Sampling point:TOP OF TOOL
DST Recovery
457.20 M SALT WATER
Date: Sampled: 1975/08/14 Received: 1975/08/19 Analyzed: 1975/08/20

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	21721.	47.388	944.8
Ca	841.	2.105	42.0
Mg	121.	0.499	10.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	34900.	49.373	984.4
HCO3	659.	0.542	10.8
SO4	89.	0.093	1.9

Specific gravity 1.0400 @ 16. C
PH 7.70 @ 21. C
Hydrogen Sulfide Description:
Calculated sodium: 21730.
TDS by Evapor. @ 110 C: 59910.

Refractive Index 1.34250 @ 25. C
Resistivity ohm/m 0.12100 @ 25. C
Calculated TDS : 58005.
TDS at Ignition : 56290.

Sample appearance:

COLORLESS WATER WITH TRACE SEDIMENT.

Remarks:

FE MUCH. F75-1189-1 1600′ ABOVE TOOL RES: .517 OHM/M @25C DARK RED WATER EXTRACTED FROM MUD. -2 1250′ ABOVE TOOL RES: .154 OHM/M @25C DARK RED WATER RECOVERED FROM MUDDY WATER. -3 600′ ABOVE TOOL RES: .121 OHM/M @25C COLORLESS WATER WITH TRACE SEDIMENT. -4 180′ ABOVE TOOL RES: .121 OHM/M @25C (SAME AS 3).

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78174 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 39666

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E84-3104-4

Well identifier	Well name	KB elev.	Gr. elev
0505041506000	PCP HIGHVALE 6-15-50-4	746.80	743.50

Interval Sampled from: 1578.00 to: 1600.00 meters KB

Formation Sampled: GLC

Sample produced by: DST # 1 Sampling point:DHS

DST Recovery
16.00 M GAS- AND OIL-CUT MUD
80.00 M GAS- AND OIL-CUT MUD

Date: Sampled: 1984/03/27 Received: 1984/03/30 Analyzed: 1984/05/01

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	12970.	45.773	564.2
K	204.	0.423	5.2
Ca	569.	2.304	28.4
Mg	170.	1.135	14.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	21080.	48.242	594.6
HCO3	969.	1.288	15.9
SO4	494.	0.835	10.3

Specific gravity 1.0250 @ 25. C
PH 7.00 @ 22. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 13298.
TDS by Evapor. @ 110 C: 36940.

Refractive Index 1.33900 @ 25. C
Resistivity ohm/m 0.19200 @ 25. C
Calculated TDS : 36087.
TDS at Ignition : 34240.

Sample appearance:

LYNES DHS REC'D @ATM PRESSURE, 2.3L OIL STAINED MUDDY WATER (2% OIL).

Remarks:

FE MUCH. E84-3104-1 TOP RES: 1.94 OHM/M @25C WATERY MUD. -2 19M RES: .448 OHM/M @25C SLIGHTLY OIL STAINED MUD. -3 TOP OF TOOL RES: .242 OHM/M @25C OIL STAINED MUDDY WATER (2% OIL).

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78174 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): 39667

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E84-3105-4

Well identifier	Well name	KB elev.	Gr. elev
0505041506000	PCP HIGHVALE 6-15-50-4	746.80	743.50

Interval Sampled from: 1572.00 to: 1577.00 meters KB

Formation Sampled: MANNVILLE

Sample produced by: DST # 2 Sampling point:DHS

DST Recovery
36.00 M GAS-CUT MUD
16.00 M GAS- AND OIL-CUT MUD

Date: Sampled: 1984/03/28 Received: 1984/03/30 Analyzed: 1984/04/27

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	6060.	43.244	263.6
K	82.	0.344	2.1
Ca	521.	4.265	26.0
Mg	214.	2.889	17.6

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	9400.	43.497	265.1
HCO3	1313.	3.530	21.5
SO4	650.	2.220	13.5
CO3	2.	0.011	0.1

Specific gravity 1.0130 @ 25. C
PH 8.40 @ 24. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 5901.
TDS by Evapor. @ 110 C: 18310.

Refractive Index 1.33600 @ 25. C
Resistivity ohm/m 0.36700 @ 25. C
Calculated TDS : 17334.
TDS at Ignition : 16810.

Sample appearance:

LYNES DHS REC'D @ATM PRESSURE, 1.6L OF OIL CUT MUDDY WATER (12% OIL).

Remarks:

FE PRESENT. E84-3105-1 TOP RES: 1.50 OHM/M @25C MUDDY WATER. -2 MIDDLE RES: 1.30 OHM/M @25C MUDDY WATER. -3 BOTTOM RES: .413 OHM/M @25C OIL CUT MUDDY WATER.

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                       | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     78170   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):     39662

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. E88-9863-3

Well identifier  Well name                                KB elev. Gr. elev
0505041214000    COLGAS DOME GENESEE 14-12-50-4             753.80    750.10

Interval Sampled from:   1560.00  to:   1562.00 meters KB
Interval Sampled from:   1563.00  to:   1564.00 meters KB

Sample produced by:                          Sampling point:METER RUN
 Date:   Sampled:  1988/06/08  Received: 1988/06/08  Analyzed: 1988/06/15

                CATIONS                                  ANIONS
|--------------------------------------|  |-------------------------------------|
|  ION  |      mg/l      | %MEQ  | MEQ/L |  |  ION  |      mg/l      | %MEQ  | MEQ/L |
|--------------------------------------|  |-------------------------------------|
|Na     |         20165.| 44.923|  877.1|  |Cl     |         34050.| 49.189|  960.4|
|K      |          1199.|  1.570|   30.7|  |HCO3   |          1227.|  1.030|   20.1|
|Ca     |           801.|  2.047|   40.0|  |SO4    |            88.|  0.094|    1.8|
|Mg     |           272.|  1.146|   22.4|  |       |               |       |       |
|       |               |       |       |  |       |               |       |       |
|--------------------------------------|  |-------------------------------------|

Specific gravity      1.0370 @  25. C   Refractive Index     1.34220 @  25. C
PH                      8.00 @  22. C   Resistivity ohm/m    0.12700 @  25. C
Hydrogen Sulfide Description:
Organics Description        :
Calculated sodium:       21153.         Calculated TDS :         56967.
TDS by Evapor. @ 110 C:        59760.   TDS at Ignition :             55660.

Sample appearance:

SAMPLE CONSISTED OF 73.95% OIL AND 46.05% SALT WATER.

Remarks:

FE PRES.
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                       | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     78173   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):     39665

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. E84-6732

Well identifier  Well name                                KB elev. Gr. elev
0505041408000    ANDEX ET AL PEMBINA 8-14-50-4              749.20    744.40

Interval Sampled from:   1563.00  to:   1567.30 meters KB

Formation Sampled: ELLERSLIE

Sample produced by:Flowing                   Sampling point:FLOWLINE
 Date:   Sampled:  1984/08/06  Received: 1984/08/10  Analyzed: 1984/08/16

                CATIONS                                  ANIONS
|--------------------------------------|  |-------------------------------------|
|  ION  |      mg/l      | %MEQ  | MEQ/L |  |  ION  |      mg/l      | %MEQ  | MEQ/L |
|--------------------------------------|  |-------------------------------------|
|Na     |         22560.| 37.020|  981.3|  |Cl     |         47000.| 50.012| 1325.7|
|K      |           399.|  0.385|   10.2|  |HCO3   |           505.|  0.312|    8.3|
|Ca     |          5526.| 10.403|  275.7|  |SO4    |           344.|  0.270|    7.2|
|Mg     |           515.|  1.599|   42.4|  |       |               |       |       |
|       |               |       |       |  |       |               |       |       |
|--------------------------------------|  |-------------------------------------|

Specific gravity      1.0500 @  25. C   Refractive Index     1.34700 @  25. C
PH                      6.90 @  24. C   Resistivity ohm/m    0.09700 @  25. C
Hydrogen Sulfide Description:
Organics Description        :
Calculated sodium:       23522.         Calculated TDS :         77155.
TDS by Evapor. @ 110 C:        93460.   TDS at Ignition :             75740.

Sample appearance:

SALT WATER WITH TRACE OIL (1% OIL).

Remarks:

FE TRACE.
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                | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78175    Chemistry number:    3
AGSWDB Hard copy number    (HRDCPNO):     39670

CORE LABORATORIES CANADA LT.                        Lab. Sample ID. 7011-84-107

Well identifier  Well name                                KB elev. Gr. elev
0505041516000    PCP HIGHVALE 16-15-50-4                     738.00    733.30

Interval Sampled from:    1553.50  to:    1557.50 meters KB

Formation Sampled: GLC

Sample produced by: DST #    1                     Sampling point:30M
  DST Recovery
        10.00 M   CLEAN OIL
 Date:    Sampled:  1984/02/11  Received: 1984/02/13  Analyzed: 1984/02/13

                 CATIONS                                 ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION  |       mg/l      | %MEQ  | MEQ/L |  |  ION  |       mg/l      | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na     |           2800.| 11.052|  121.8|  |Cl     |          18136.| 46.422|  511.6|
|K      |          16850.| 39.105|  430.9|  |HCO3   |           1096.|  1.630|   18.0|
|Ca     |            160.|  0.725|    8.0|  |SO4    |            149.|  0.282|    3.1|
|Mg     |            105.|  0.784|    8.6|  |       |                |       |       |
|       |                |       |       |  |       |                |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity      1.0250 @  15. C   Refractive Index      1.33730 @  25. C
PH                      8.00 @   0. C   Resistivity ohm/m     0.17000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:        11863.        Calculated TDS :           30952.

Remarks:

FE PRESENT. NACL EQUIV 38520.
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                | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78175    Chemistry number:    4
AGSWDB Hard copy number    (HRDCPNO):     39671

CORE LABORATORIES CANADA LT.                        Lab. Sample ID. 7011-84-107

Well identifier  Well name                                KB elev. Gr. elev
0505041516000    PCP HIGHVALE 16-15-50-4                     738.00    733.30

Interval Sampled from:    1553.50  to:    1557.50 meters KB

Formation Sampled: GLC

Sample produced by: DST #    1                     Sampling point:10M
  DST Recovery
        10.00 M   CLEAN OIL
 Date:    Sampled:  1984/02/11  Received: 1984/02/13  Analyzed: 1984/02/13

                 CATIONS                                 ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION  |       mg/l      | %MEQ  | MEQ/L |  |  ION  |       mg/l      | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na     |           2850.| 11.379|  124.0|  |Cl     |          18117.| 46.905|  511.0|
|K      |          16400.| 38.497|  419.4|  |HCO3   |           1065.|  1.602|   17.5|
|Ca     |            166.|  0.760|    8.3|  |SO4    |            160.|  0.306|    3.3|
|Mg     |             73.|  0.551|    6.0|  |       |                |       |       |
|       |                |       |       |  |       |                |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity      1.0249 @  15. C   Refractive Index      1.33780 @  25. C
PH                      8.00 @   0. C   Resistivity ohm/m     0.17000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:        11898.        Calculated TDS :           30938.

Remarks:

FE TRACE. NACL EQUIV 38040.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78175 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 39668

CORE LABORATORIES CANADA LT. Lab. Sample ID. 7024-84-044

Well identifier	Well name	KB elev.	Gr. elev
0505041516000	PCP HIGHVALE 16-15-50-4	738.00	733.30

Interval Sampled from: 1553.50 to: 1557.50 meters KB

Formation Sampled: ELERSLIE

Sample produced by:Swabbing Sampling point:
Date: Sampled: 1984/02/24 Received: 1984/03/01 Analyzed: 1984/03/01

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	18700.	43.494	813.4
K	1850.	2.530	47.3
Ca	652.	1.740	32.5
Mg	189.	0.832	15.6

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	33512.	50.544	945.3
HCO3	925.	0.811	15.2
SO4	45.	0.050	0.9

Specific gravity 1.0415 @ 15. C
PH 7.60 @ 0. C
Hydrogen Sulfide Description:
Calculated sodium: 20997.

Refractive Index 1.34300 @ 25. C
Resistivity ohm/m 0.13000 @ 25. C
Calculated TDS : 55850.

Remarks:

FE PRESENT. NACL EQUIV 55335.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78175 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): 39669

CORE LABORATORIES CANADA LT. Lab. Sample ID. 7011-84-107

Well identifier	Well name	KB elev.	Gr. elev
0505041516000	PCP HIGHVALE 16-15-50-4	738.00	733.30

Interval Sampled from: 1553.50 to: 1557.50 meters KB

Formation Sampled: GLC

Sample produced by: DST # 1 Sampling point:BHS
DST Recovery
10.00 M CLEAN OIL
Date: Sampled: 1984/02/10 Received: 1984/02/13 Analyzed: 1984/02/13

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	5400.	19.435	234.9
K	13850.	29.307	354.2
Ca	183.	0.756	9.1
Mg	81.	0.551	6.7

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	20171.	47.075	569.0
HCO3	1840.	2.495	30.2
SO4	221.	0.381	4.6

Specific gravity 1.0278 @ 15. C
PH 8.10 @ 0. C
Hydrogen Sulfide Description:
Calculated sodium: 13517.

Refractive Index 1.33870 @ 25. C
Resistivity ohm/m 0.16500 @ 25. C
Calculated TDS : 35078.

Remarks:

FE TRACE, NACL EQUIV 40368.

| AGSWDB WATER ANALYSIS REPORT |

AGSWDB Well site identifier (SITID): 78186 Chemistry number: 3
AGSWDB Hard copy number (HRDCPNO): 39683

AGAT ENGINEERING LTD Lab. Sample ID. 5479

Well identifier	Well name	KB elev.	Gr. elev
0505042416000	COLGAS DOME HIGHVALE 16-24-50-4	732.80	729.10

Interval Sampled from: 1633.00 to: 1649.00 meters KB

Formation Sampled: ELLERSLIE

Sample produced by: DST # 1 Sampling point:TOP OF RECOVERY
DST Recovery
120.00 M MUD
20.00 M OIL-CUT MUD
Date: Sampled: 1983/06/23 Received: 1983/06/27 Analyzed: 1983/07/04

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	1770.	49.927	77.0
K	21.	0.340	0.5
Ca	10.	0.320	0.5
Mg	4.	0.213	0.3

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	1920.	35.119	54.2
HCO3	762.	8.098	12.5
SO4	395.	5.333	8.2
CO3	30.	0.648	1.0

Specific gravity 1.0030 @ 25. C
PH 9.26 @ 25. C Resistivity ohm/m 1.51000 @ 25. C
Hydrogen Sulfide Description:
Calculated sodium: 1725. Calculated TDS : 4459.
TDS by Evapor. @ 110 C: 4570. TDS at Ignition : 4170.

TDS by evaporation @ 180. C : 4540. mg/l

Sample appearance:

"30 MIN." API FILTRATE LOSS IS 11.65ML. WATER EXTRACTED FROM MUD.

Remarks:

THE SAMPLE CONTAINED IONS (INHIBITORS?) WHICH INTERFERED WITH THE ALKALINITY TEST. FE TRACE+

| AGSWDB WATER ANALYSIS REPORT |

AGSWDB Well site identifier (SITID): 78186 Chemistry number: 4
AGSWDB Hard copy number (HRDCPNO): 39684

AGAT ENGINEERING LTD Lab. Sample ID. 5479

Well identifier	Well name	KB elev.	Gr. elev
0505042416000	COLGAS DOME HIGHVALE 16-24-50-4	732.80	729.10

Interval Sampled from: 1633.00 to: 1649.00 meters KB

Formation Sampled: ELLERSLIE

Sample produced by: DST # 1 Sampling point:10M ABOVE TOOL
DST Recovery
120.00 M MUD
20.00 M OIL-CUT MUD
Date: Sampled: 1983/06/23 Received: 1983/06/27 Analyzed: 1983/07/04

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	8720.	46.855	379.3
K	156.	0.493	4.0
Ca	359.	2.213	17.9
Mg	113.	1.149	9.3
Fe	0.10000	0.000	0.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	13800.	48.084	389.2
HCO3	224.	0.453	3.7
SO4	293.	0.754	6.1

Specific gravity 1.0170 @ 25. C
PH 8.08 @ 25. C Resistivity ohm/m 0.31000 @ 25. C
Calculated sodium: 8549. Calculated TDS : 23224.
TDS by Evapor. @ 110 C: 23400. TDS at Ignition : 22400.

TDS by evaporation @ 180. C : 23400. mg/l

Remarks:

SAMPLE CONTAINS IONS (INHIBITORS?) WHICH INTERFERED WITH THE ALKALINITY TEST.

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                    | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     78186   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):     39681

AGAT ENGINEERING LTD                               Lab. Sample ID. 5625

Well identifier  Well name                                KB elev. Gr. elev
0505042416000    COLGAS DOME HIGHVALE 16-24-50-4             732.80    729.10

Interval Sampled from:   1555.00  to:   1557.50 meters KB

Formation Sampled: BF

Sample produced by:                              Sampling point:WELLHEAD
 Date:   Sampled:  1983/08/30  Received: 1983/08/31  Analyzed: 1983/04/07

               CATIONS                                  ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |  |  ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na      |       23800.| 44.732| 1035.2|  |Cl      |       40500.| 49.360| 1142.4|
|K       |         963.|  1.064|   24.6|  |HCO3    |         607.|  0.430|    9.9|
|Ca      |        1460.|  3.148|   72.9|  |SO4     |          37.|  0.033|    0.8|
|Mg      |         317.|  1.127|   26.1|  |        |             |       |       |
|Fe      |          68.|  0.105|    2.4|  |        |             |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity      1.0470 @  25. C
PH                      6.87 @  25. C   Resistivity ohm/m    0.14000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:         24237.       Calculated TDS :          66849.
TDS by Evapor. @ 110 C:        68900.   TDS at Ignition :              65200.

TDS by evaporation @  180. C :      67700. mg/l
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                    | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     78186   Chemistry number:    2
AGSWDB Hard copy number   (HRDCPNO):     39682

AGAT ENGINEERING LTD                               Lab. Sample ID. E4013

Well identifier  Well name                                KB elev. Gr. elev
0505042416000    COLGAS DOME HIGHVALE 16-24-50-4             732.80    729.10

Interval Sampled from:   1565.00  to:   1566.00 meters KB

Formation Sampled: ELLERSLIE

Sample produced by:                              Sampling point:RIG TANK
 Date:   Sampled:  1983/08/04  Received: 1983/08/09  Analyzed: 1983/08/12

               CATIONS                                  ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |  |  ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na      |   .   20200.| 41.102|  878.7|  |Cl      |       39100.| 51.591| 1102.9|
|K       |        1200.|  1.436|   30.7|  |HCO3    |         453.|  0.347|    7.4|
|Ca      |        1860.|  4.342|   92.8|  |SO4     |         201.|  0.196|    4.2|
|Mg      |         254.|  0.978|   20.9|  |        |             |       |       |
|Fe      |           5.|  0.009|    0.2|  |        |             |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity      1.0410 @  25. C
PH                      7.53 @  25. C   Resistivity ohm/m    0.11000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:         23009.       Calculated TDS :          64647.
TDS by Evapor. @ 110 C:        63500.   TDS at Ignition :              59700.

TDS by evaporation @  180. C :      62400. mg/l
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     78197   Chemistry number:    2
AGSWDB Hard copy number    (HRDCPNO):    39703

CHEMICAL & GEOLOGICAL LAB LTD                 Lab. Sample ID. E82-11446

Well identifier  Well name                               KB elev. Gr. elev
0505042914000    ANDEX ET AL HIGHVALE 14-29-50-4           758.50    754.40

Interval Sampled from:    1595.00   to:    1598.00 meters KB

Formation Sampled: BF

Sample produced by:                              Sampling point:
                      CATIONS                                 ANIONS
|------------------------------------|   |-------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |   |  ION   |     mg/l     | %MEQ  | MEQ/L |
|------------------------------------|   |-------------------------------------|
|Na      |       24987.| 43.454| 1086.9|   |Cl      |       44000.| 49.620| 1241.1|
|K       |         456.|  0.466|   11.7|   |HCO3    |         500.|  0.328|    8.2|
|Ca      |        1834.|  3.659|   91.5|   |SO4     |          70.|  0.058|    1.5|
|Mg      |         734.|  2.415|   60.4|   |        |             |       |       |
|        |             |       |       |   |        |             |       |       |
|------------------------------------|   |-------------------------------------|

Specific gravity       1.0500 @  25. C   Refractive Index      1.34510 @  25. C
PH                       5.70 @  22. C   Resistivity ohm/m     0.11000 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:        25264.         Calculated TDS :          72148.
TDS by Evapor. @ 110 C:        73260.    TDS at Ignition :               69160.

Sample appearance:

SALT WATER.

Remarks:

FE MUCH.
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     78197   Chemistry number:    4
AGSWDB Hard copy number    (HRDCPNO):    39705

CHEMICAL & GEOLOGICAL LAB LTD                 Lab. Sample ID. E82-741

Well identifier  Well name                               KB elev. Gr. elev
0505042914000    ANDEX ET AL HIGHVALE 14-29-50-4           758.50    754.40

Interval Sampled from:    1595.00   to:    1598.00 meters KB

Formation Sampled: LOWER MANNVILLE

Sample produced by:                              Sampling point:
 Date:   Sampled:  1982/05/24  Received: 1982/05/25  Analyzed: 1982/05/28

                      CATIONS                                 ANIONS
|------------------------------------|   |-------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |   |  ION   |     mg/l     | %MEQ  | MEQ/L |
|------------------------------------|   |-------------------------------------|
|Na      |       25950.| 46.588| 1128.8|   |Cl      |       42000.| 48.895| 1184.7|
|K       |         186.|  0.196|    4.8|   |HCO3    |         583.|  0.394|    9.6|
|Ca      |        1682.|  3.464|   83.9|   |SO4     |          60.|  0.052|    1.2|
|Mg      |         121.|  0.411|   10.0|   |        |             |       |       |
|        |             |       |       |   |        |             |       |       |
|------------------------------------|   |-------------------------------------|

Specific gravity       1.0470 @  25. C   Refractive Index      1.34450 @  25. C
PH                       7.40 @  22. C   Resistivity ohm/m     0.10400 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:        25327.         Calculated TDS :          69477.
TDS by Evapor. @ 110 C:        80160.    TDS at Ignition :               61660.

Remarks:

FE TRACE.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78194 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 39696

CORE LABORATORIES CANADA LT. Lab. Sample ID. 7011-7728

Well identifier	Well name	KB elev.	Gr. elev
0505042810000	ANDEX ET AL HIGHVALE 10-28-50-4	758.60	754.70

Interval Sampled from: 1568.20 to: 1570.94 meters KB

Formation Sampled: LOWER MANNVILLE

Sample produced by: Sampling point:WELLHEAD
Date: Sampled: 1977/11/03 Received: 1977/11/07 Analyzed: 1977/11/28

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	25200.	47.017	1096.1
K	177.	0.194	4.5
Ca	923.	1.976	46.1
Mg	233.	0.822	19.2

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	40843.	49.415	1152.0
HCO3	810.	0.569	13.3
SO4	7.	0.006	0.1

Specific gravity 1.0469 @ 16. C
PH 7.10 @ 0. C
Hydrogen Sulfide Description:
Calculated sodium: 25296.
Refractive Index 1.34300 @ 24. C
Resistivity ohm/m 0.09600 @ 25. C
Calculated TDS : 67700.

Remarks:

FE TRACE. NACL EQUIV 67786.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78197 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 39702

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E82-1653

Well identifier	Well name	KB elev.	Gr. elev
0505042914000	ANDEX ET AL HIGHVALE 14-29-50-4	758.50	754.40

Interval Sampled from: 1595.00 to: 1598.00 meters KB

Formation Sampled: LOWER MANNVILLE

Sample produced by: Sampling point:
Date: Sampled: 1982/06/14 Received: 1982/06/16 Analyzed: 1982/06/25

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	25800.	47.259	1122.2
K	441.	0.475	11.3
Ca	1001.	2.103	50.0
Mg	97.	0.336	8.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	41500.	49.294	1170.6
HCO3	695.	0.480	11.4
SO4	60.	0.053	1.2

Specific gravity 1.0390 @ 25. C
PH 7.80 @ 23. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 25872.
TDS by Evapor. @ 110 C: 71040.
Refractive Index 1.34500 @ 25. C
Resistivity ohm/m 0.11000 @ 25. C
Calculated TDS : 68872.
TDS at Ignition : 65540.

Remarks:

FE PRESENT.

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                       | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     78201    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):    39711

CHEMICAL & GEOLOGICAL LAB LTD                  Lab. Sample ID. E81-6151-3

Well identifier  Well name                                  KB elev. Gr. elev
0505043009000    ANDEX HIGHVALE 9-30-50-4                      773.40    769.30

Interval Sampled from:    1620.00   to:    1626.00 meters KB

Formation Sampled: BANFF

Sample produced by: DST #     1                Sampling point:BOTTOM
  DST Recovery
         1.90 M3  CLEAN OIL
         0.20 M3  MUD-CUT OIL
         0.10 M3  OIL-CUT SALT WATER
 Date:   Sampled:  1981/09/04  Received: 1981/09/09  Analyzed: 1981/09/22

               CATIONS                                   ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION   |      mg/l     | %MEQ  | MEQ/L |  |  ION   |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na      |         27640.| 44.490| 1202.3|  |Cl      |         47400.| 49.475| 1337.0|
|K       |           658.|  0.623|   16.8|  |HCO3    |           539.|  0.327|    8.8|
|Ca      |          1634.|  3.017|   81.5|  |SO4     |           265.|  0.204|    5.5|
|Mg      |           612.|  1.864|   50.4|  |        |               |       |       |
|        |               |       |       |  |        |               |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity       1.0520 @  25. C   Refractive Index      1.34600 @  25. C
PH                       7.20 @  23. C   Resistivity ohm/m     0.10400 @  25. C
Hydrogen Sulfide Description:
Organics Description        :
Calculated sodium:        28037.         Calculated TDS :           78213.
TDS by Evapor. @ 110 C:        79380.    TDS at Ignition :               74600.

Sample appearance:

MURKY SALT WATER WITH TRACE OF OIL.

Remarks:

FE NIL. E81-6151-1 TOP RES: .112 OHM/M @25C MUD, TRACE OF OIL.
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                       | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     78206    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):    39720

CHEMICAL & GEOLOGICAL LAB LTD                  Lab. Sample ID. E84-1609-3

Well identifier  Well name                                  KB elev. Gr. elev
0505043116000    ANDEX ET AL HIGHVALE 16-31-50-4               762.00    757.90

Interval Sampled from:    1597.00   to:    1608.00 meters KB

Formation Sampled: BF

Sample produced by: DST #     1                Sampling point:BOTTOM
  DST Recovery
        20.00 M   CLEAN OIL
        84.00 M   GAS- AND OIL-CUT MUD
 Date:   Sampled:  1984/02/15  Received: 1984/02/21  Analyzed: 1984/03/16

               CATIONS                                   ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION   |      mg/l     | %MEQ  | MEQ/L |  |  ION   |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na      |          8690.| 42.988|  378.0|  |Cl      |         15210.| 48.791|  429.0|
|K       |           167.|  0.486|    4.3|  |HCO3    |           634.|  1.182|   10.4|
|Ca      |           440.|  2.497|   22.0|  |SO4     |           848.|  2.008|   17.7|
|Mg      |           219.|  2.049|   18.0|  |        |               |       |       |
|        |               |       |       |  |        |               |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity       1.0160 @  25. C   Refractive Index      1.33750 @  25. C
PH                       7.90 @  21. C   Resistivity ohm/m     0.26800 @  25. C
Hydrogen Sulfide Description:
Organics Description        :
Calculated sodium:         9590.         Calculated TDS :           26618.
TDS by Evapor. @ 110 C:        27070.    TDS at Ignition :               24980.

Sample appearance:

70% OIL, 30% MUDDY SALTY WATER.

Remarks:

FE TRACE. E84-1609-1 TOP RES: .891 OHM/M @25C SLIGHTLY OIL STAINED MUD. -2 MID
DLE RES: .818 OHM/M @25C SLIGHTLY OIL STAINED MUD.
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):       78197    Chemistry number:     5
AGSWDB Hard copy number    (HRDCPNO):      39706

CHEMICAL & GEOLOGICAL LAB LTD                        Lab. Sample ID. E82-0706

Well identifier  Well name                                 KB elev. Gr. elev
0505042914000    ANDEX ET AL HIGHVALE 14-29-50-4              758.50    754.40

Interval Sampled from:    1595.00   to:    1598.00 meters KB

Formation Sampled: LOWER MANNVILLE

Sample produced by:                                 Sampling point:PRODUCTION TANK
 Date:    Sampled:  1982/05/12  Received: 1982/05/13  Analyzed: 1982/05/18

                 CATIONS                                     ANIONS
|------------------------------------|    |-------------------------------------|
|  ION  |      mg/l     | %MEQ  | MEQ/L |    |  ION  |      mg/l     | %MEQ  | MEQ/L |
|------------------------------------|    |-------------------------------------|
|Na     |        26490.| 46.302| 1152.3|    |Cl     |        43100.| 48.852| 1215.7|
|K      |          756.|  0.777|   19.3|    |HCO3   |          844.|  0.556|   13.8|
|Ca     |         1305.|  2.617|   65.1|    |SO4    |           72.|  0.060|    1.5|
|Mg     |          253.|  0.837|   20.8|    |       |              |       |       |
|       |              |       |       |    |       |              |       |       |
|------------------------------------|    |-------------------------------------|

Specific gravity        1.0440 @  25. C    Refractive Index      1.34490 @  25. C
PH                        7.40 @  23. C    Resistivity ohm/m     0.10300 @  25. C
Hydrogen Sulfide Description:
Organics Description         :
Calculated sodium:         26328.          Calculated TDS :           71473.
TDS by Evapor. @ 110 C:         72580.     TDS at Ignition :              64980.

Remarks:

FE PRESENT.
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):       78197    Chemistry number:     6
AGSWDB Hard copy number    (HRDCPNO):      39707

CHEMICAL & GEOLOGICAL LAB LTD                        Lab. Sample ID. E81-9892-4

Well identifier  Well name                                 KB elev. Gr. elev
0505042914000    ANDEX ET AL HIGHVALE 14-29-50-4              758.50    754.40

Interval Sampled from:    1594.00   to:    1599.00 meters KB

Formation Sampled: LOWER MANNVILLE

Sample produced by: DST #     1                     Sampling point:DHS
  DST Recovery
         2.00 M    MUD
        98.00 M    OIL-CUT SALT WATER
                 CATIONS                                     ANIONS
|------------------------------------|    |-------------------------------------|
|  ION  |      mg/l     | %MEQ  | MEQ/L |    |  ION  |      mg/l     | %MEQ  | MEQ/L |
|------------------------------------|    |-------------------------------------|
|Na     |        23168.| 46.867| 1007.8|    |Cl     |        37400.| 49.061| 1054.9|
|K      |          322.|  0.383|    8.2|    |HCO3   |         1032.|  0.787|   16.9|
|Ca     |          773.|  1.794|   38.6|    |SO4    |          165.|  0.160|    3.4|
|Mg     |          248.|  0.949|   20.4|    |       |              |       |       |
|       |              |       |       |    |       |              |       |       |
|------------------------------------|    |-------------------------------------|

Specific gravity        1.0430 @  25. C    Refractive Index      1.34400 @  25. C
PH                        6.90 @  21. C    Resistivity ohm/m     0.11800 @  25. C
Hydrogen Sulfide Description:
Organics Description         :
Calculated sodium:         23366.          Calculated TDS :           62460.
TDS by Evapor. @ 110 C:         63920.     TDS at Ignition :              58500.

Sample appearance:

MURKY SALT WATER WITH TRACE OIL. QUINN DHS REC'D @700 KPA, GAS AND 1.2L MURKY
SALT WATER WITH TRACE OF OIL.

Remarks:

FE PRESENT. E81-9892-2 56M RES: .288 OHM/M @25C MUDDY WATER OIL SCUM. -3 1M RE
S: .121 OHM/M @25C MUDDY WATER TRACE OIL.
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78222    Chemistry number:    3
AGSWDB Hard copy number    (HRDCPNO):     39746

CHEMEX LABS (ALBERTA) LTD.                         Lab. Sample ID. 85-0201-0908

Well identifier  Well name                                     KB elev. Gr. elev
0505050314000    CDNOXY ET AL PEMBINA 14-3-50-5                   755.10    750.80

Interval Sampled from:   1666.50  to:   1668.50 meters KB
Interval Sampled from:   1669.50  to:   1671.50 meters KB

Formation Sampled: BF6440

Sample produced by:                                Sampling point:RIG TANK
                  CATIONS                                        ANIONS
|--------------------------------------|  |--------------------------------------|
|  ION   |     mg/l      | %MEQ  | MEQ/L |  |  ION   |     mg/l      | %MEQ  | MEQ/L |
|--------------------------------------|  |--------------------------------------|
|Na      |        24380.| 45.753| 1060.5|  |Cl      |        40000.| 48.678| 1128.3|
|K       |         1134.|  1.251|   29.0|  |HCO3    |         1160.|  0.820|   19.0|
|Ca      |         1110.|  2.390|   55.4|  |SO4     |           30.|  0.027|    0.6|
|Mg      |          300.|  1.065|   24.7|  |        |              |       |       |
|Fe      |           10.|  0.016|    0.4|  |        |              |       |       |
|--------------------------------------|  |--------------------------------------|

Specific gravity       1.0510 @    5. C   Refractive Index      1.34510 @  25. C
PH                       7.30 @    5. C   Resistivity ohm/m     1.05000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:         24551.         Calculated TDS :          66562.
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78230    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     39750

CHEMICAL & GEOLOGICAL LAB LTD                      Lab. Sample ID. E74-2130-2

Well identifier  Well name                                     KB elev. Gr. elev
0505051107000    NORTERRA ET AL LINDALE 7-11-50-5                 760.20    757.10

Interval Sampled from:   1602.64  to:   1619.71 meters KB

Formation Sampled: GLAUC

Sample produced by: DST #    1                     Sampling point:MIDDLE
  DST Recovery
        18.30 M   MUD
       378.00 M   GAS-CUT WATER
 Date:   Sampled:  1974/06/20  Received: 1974/06/27

                  CATIONS                                        ANIONS
|--------------------------------------|  |--------------------------------------|
|  ION   |     mg/l      | %MEQ  | MEQ/L |  |  ION   |     mg/l      | %MEQ  | MEQ/L |
|--------------------------------------|  |--------------------------------------|
|Na      |        26473.| 47.306| 1151.5|  |Cl      |        42850.| 49.653| 1208.6|
|Ca      |          991.|  2.032|   49.5|  |HCO3    |          476.|  0.320|    7.8|
|Mg      |          194.|  0.656|   16.0|  |SO4     |           39.|  0.033|    0.8|
|        |              |       |       |  |        |              |       |       |
|--------------------------------------|  |--------------------------------------|

Specific gravity       1.0500 @   16. C   Refractive Index      1.34470 @  25. C
PH                       7.40 @   26. C   Resistivity ohm/m     0.15000 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:         26483.         Calculated TDS :          70791.
TDS by Evapor. @ 110 C:         76320.    TDS at Ignition :              66340.

Sample appearance:

COLORLESS WATER RECOVERED FROM MUDDY WATER.

Remarks:

FE PRESENT. E74-2130-1 TOP RES: .239 OHM/M @25C YELLOW WATER RECOVERED FROM MU
DDY WATER. -3 BOTTOM RES: .232 OHM/M @25C SAME AS 1.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78207 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 39724

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E87-3775

Well identifier	Well name	KB elev.	Gr. elev
0505043202000	ANDEX COLGAS HIGHVALE 2-32-50-4	773.20	769.10

Interval Sampled from: 1604.00 to: 1616.00 meters KB

Formation Sampled: BF 6440

Sample produced by: Sampling point:WELLHEAD
Date: Sampled: 1987/02/23 Received: 1987/02/24 Analyzed: 1987/03/04

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	27900.	44.889	1213.6
K	379.	0.359	9.7
Ca	1281.	2.364	63.9
Mg	525.	1.598	43.2
Fe	0.14000	0.000	0.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	47800.	49.870	1348.3
I	12.	0.004	0.1
HCO3	1237.	0.750	20.3
SO4	216.	0.166	4.5

Other Determinations

Parameter	mg/l
barium	2.
boron	7.
strontium	146.

Specific gravity 1.0500 @ 25. C Refractive Index 1.34550 @ 25. C
PH 7.40 @ 21. C Resistivity ohm/m 0.10400 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 29108. Calculated TDS : 79550.

Sample appearance:

SAMPLE CONSISTED OF EMULSIFIED OIL AND SALT WATER.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78213 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 39727

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID: E77-7628-3

Well identifier	Well name	KB elev.	Gr. elev
0505043310000	ANDEX ET AL HIGHVALE 10-33-50-4	764.70	760.80

Interval Sampled from: 1575.82 to: 1583.44 meters KB

Formation Sampled: NORDEGG

Sample produced by: DST # 1 Sampling point:BOTTOM
DST Recovery
36.60 M CLEAN OIL
18.30 M OIL-CUT MUD
61.30 M GAS- AND OIL-CUT MUD
Date: Sampled: 1977/06/28 Received: 1977/07/05 Analyzed: 1977/08/09

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	7514.	45.537	326.8
Ca	377.	2.621	18.8
Mg	160.	1.834	13.2

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	12200.	47.944	344.1
HCO3	603.	1.377	9.9
SO4	237.	0.687	4.9

Specific gravity 1.0140 @ 16. C Refractive Index 1.33550 @ 25. C
PH 8.00 @ 25. C Resistivity ohm/m 0.41100 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 7517. Calculated TDS : 20788.
TDS by Evapor. @ 110 C: 22500. TDS at Ignition : 20345.

Sample appearance:

COLORLESS WATER RECOVERED FROM OIL CUT MUDDY WATER.

Remarks:

FE PRESENT. E77-7628-2 MIDDLE OIL CUT MUD, NO ANALYSIS.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78231 Chemistry number: 4
AGSWDB Hard copy number (HRDCPNO): 39754

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E79-14396-3

Well identifier	Well name	KB elev.	Gr. elev
0505051205000	ANDEX ET AL HIGHVALE 5-12-50-5	772.80	768.70

Interval Sampled from: 1646.00 to: 1652.00 meters KB

Formation Sampled: OSTRACOD

Sample produced by: DST # 3 Sampling point:BHS #1513
DST Recovery
8.00 M MUD
14.00 M GAS-CUT MUD
Date: Sampled: 1979/09/13 Received: 1979/09/17 Analyzed: 1979/10/02

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	2477.	48.807	107.7
K	21.	0.243	0.5
Ca	27.	0.610	1.3
Mg	9.	0.335	0.7

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	3115.	39.802	87.9
HCO3	602.	4.469	9.9
SO4	595.	5.612	12.4
CO3	8.	0.121	0.3

Specific gravity 1.0040 @ 25. C
PH 8.40 @ 24. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 2490.
TDS by Evapor. @ 110 C: 6915.

Refractive Index 1.33320 @ 25. C
Resistivity ohm/m 0.91900 @ 25. C
Calculated TDS : 6540.
TDS at Ignition : 6260.

Sample appearance:

QUINN DHS REC'D @ATM PRESSURE, 2100MLS SALTY MUDDY WATER.

Remarks:

FE TRACE. E79-14396-1 22M ABOVE TOOL RES OF FILT: 1.51 OHM/M @25C MUD. -2 1.52 4M ABOVE TOOL RES OF FILT: 1.27 OHM/M @25C MUD.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 78236 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 39762

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E79-10739-5

Well identifier	Well name	KB elev.	Gr. elev
0505052310000	ANDEX ET AL HIGHVALE 10-23-50-5	757.80	753.70

Interval Sampled from: 1631.50 to: 1642.00 meters KB

Formation Sampled: BF

Sample produced by: DST # 1 Sampling point:TOOL
DST Recovery
150.00 M CLEAN OIL
Date: Sampled: 1979/06/13 Received: 1979/06/18 Analyzed: 1979/06/29

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na+K	16968.		
Ca	469.	2.862	23.4
Mg	199.	2.002	16.4

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	26750.	92.261	754.5
HCO3	671.	1.345	11.0
SO4	601.	1.530	12.5

Specific gravity 1.0300 @ 25. C
PH 7.80 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 16974.
TDS by Evapor. @ 110 C: 46200.

Refractive Index 1.34050 @ 25. C
Resistivity ohm/m 0.15100 @ 25. C
Calculated TDS : 45323.
TDS at Ignition : 43500.

Remarks:

FE NIL.

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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78231    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     39751

CHEMICAL & GEOLOGICAL LAB LTD                 Lab. Sample ID. E79-15184-1

Well identifier  Well name                            KB elev. Gr. elev
0505051205000    ANDEX ET AL HIGHVALE 5-12-50-5          772.80    768.70

Interval Sampled from:    1646.00   to:    1652.00 meters KB

Formation Sampled: OST

Sample produced by:                           Sampling point:#1
 Date:    Sampled:  1979/10/11   Received: 1979/10/12  Analyzed: 1979/10/16

                 CATIONS                                     ANIONS
|------------------------------------|   |------------------------------------|
| ION  |       mg/l   | %MEQ  | MEQ/L |   | ION  |       mg/l   | %MEQ  | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na    |       25678. | 45.573| 1116.9|   |Cl    |       43000. | 49.487| 1212.9|
|K     |         361. | 0.377 |    9.2|   |HCO3  |         705. | 0.471 |   11.6|
|Ca    |        1490. | 3.034 |   74.4|   |SO4   |          56. | 0.048 |    1.2|
|Mg    |         301. | 1.011 |   24.8|   |      |              |       |       |
|      |              |       |       |   |      |              |       |       |
|------------------------------------|   |------------------------------------|

Specific gravity       1.0480 @  25. C   Refractive Index      1.34500 @  25. C
PH                       6.90 @  24. C   Resistivity ohm/m     0.11900 @  25. C
Hydrogen Sulfide Description:
Organics Description            :
Calculated sodium:         25900.        Calculated TDS :          71093.
TDS by Evapor. @ 110 C:          73620.  TDS at Ignition :                67980.

Remarks:

FE PRESENT.
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      78231    Chemistry number:    2
AGSWDB Hard copy number    (HRDCPNO):     39752

CHEMICAL & GEOLOGICAL LAB LTD                 Lab. Sample ID. E79-15184-2

Well identifier  Well name                            KB elev. Gr. elev
0505051205000    ANDEX ET AL HIGHVALE 5-12-50-5          772.80    768.70

Interval Sampled from:    1646.00   to:    1652.00 meters KB

Formation Sampled: OST

Sample produced by:                           Sampling point:#2
 Date:    Sampled:  1979/10/11   Received: 1979/10/12  Analyzed: 1979/10/16

                 CATIONS                                     ANIONS
|------------------------------------|   |------------------------------------|
| ION  |       mg/l   | %MEQ  | MEQ/L |   | ION  |       mg/l   | %MEQ  | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na    |       26282. | 45.531| 1143.2|   |Cl    |       44200. | 49.654| 1246.7|
|K     |         362. | 0.369 |    9.3|   |HCO3  |         498. | 0.325 |    8.2|
|Ca    |        1537. | 3.055 |   76.7|   |SO4   |          33. | 0.027 |    0.7|
|Mg    |         317. | 1.039 |   26.1|   |      |              |       |       |
|      |              |       |       |   |      |              |       |       |
|------------------------------------|   |------------------------------------|

Specific gravity       1.0500 @  25. C   Refractive Index      1.34550 @  25. C
PH                       6.90 @  24. C   Resistivity ohm/m     0.11100 @  25. C
Hydrogen Sulfide Description:
Organics Description            :
Calculated sodium:         26505.        Calculated TDS :          72837.
TDS by Evapor. @ 110 C:          75680.  TDS at Ignition :                70580.

Remarks:

FE PRESENT.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80735 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 44545

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E80-13493-3

Well identifier	Well name	KB elev.	Gr. elev
0515040313000	ANDEX ET AL HIGHVALE 13-3-51-4	764.30	760.20

Interval Sampled from: 1578.00 to: 1586.00 meters KB

Formation Sampled: OSTRACODE

Sample produced by: DST # 1 Sampling point:0 M ABO TOOL
DST Recovery
948.00 M CLEAN OIL
2.00 M SALT WATER
Date: Sampled: 1980/11/16 Received: 1980/11/25 Analyzed: 1980/12/16

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	1715.	48.734	74.6
K	18.	0.301	0.5
Ca	21.	0.685	1.0
Mg	5.	0.269	0.4

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	1717.	31.639	48.4
HCO3	1434.	15.353	23.5
SO4	222.	3.020	4.6

Specific gravity 1.0030 @ 25. C
PH 8.40 @ 21. C
Refractive Index 1.33360 @ 25. C
Resistivity ohm/m 1.36000 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 1726.
TDS by Evapor. @ 110 C: 4530.
Calculated TDS : 4397.
TDS at Ignition : 4125.

Remarks:

FE NIL.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80735 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): 44546

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID.:E79-7331-3

Well identifier	Well name	KB elev.	Gr. elev
0515040313000	ANDEX ET AL HIGHVALE 13-3-51-4	764.30	760.20

Interval Sampled from: 1578.50 to: 1586.50 meters KB

Formation Sampled: OST, ELRSL

Sample produced by: DST # 1 Sampling point:TOP OF TOOL
DST Recovery
948.00 M CLEAN OIL
2.00 M SALT WATER
Date: Sampled: 1979/03/01 Received: 1979/03/05 Analyzed: 1979/03/16

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na+K	22699.		
Ca	1214.	5.255	60.6
Mg	267.	1.906	22.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	37200.	91.026	1049.3
HCO3	1139.	1.619	18.7
SO4	107.	0.193	2.2

Specific gravity 1.0400 @ 25. C
PH 7.70 @ 20. C
Refractive Index 1.34360 @ 25. C
Resistivity ohm/m 0.11300 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 22707.
TDS by Evapor. @ 110 C: 64820.
Calculated TDS : 62055.
TDS at Ignition : 60400.

Sample appearance:

SAMPLE CONSISTED OF MUDDY WATER WITH A TRACE OF OIL.

Remarks:

FE PRES.

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                | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      80744    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     44549

CHEMICAL & GEOLOGICAL LAB LTD                     Lab. Sample ID. E83-14182-2

                                                         KB elev. Gr. elev
Well identifier  Well name
0515040506000    ANDEX ET AL HIGHVALE 6-5-51-4             761.50    757.40

Interval Sampled from:    1601.50  to:    1612.00 meters KB

Formation Sampled: BF 6440

Sample produced by: DST #     1                   Sampling point:BOTTOM
  DST Recovery
        15.00 M    MUD
        10.00 M    OIL-CUT MUD
 Date:    Sampled:  1983/06/20  Received: 1983/06/23  Analyzed: 1983/06/30

                 CATIONS                                   ANIONS
|---------------------------------------|  |---------------------------------------|
|  ION   |     mg/l     | %MEQ   | MEQ/L |  |  ION   |     mg/l     | %MEQ   | MEQ/L |
|---------------------------------------|  |---------------------------------------|
|Na      |       12210.| 45.700|  531.1|  |Cl      |       19640.| 47.668|  554.0|
|K       |         171.|  0.376|    4.4|  |HCO3    |         727.|  1.025|   11.9|
|Ca      |         701.|  3.010|   35.0|  |SO4     |         473.|  0.847|    9.8|
|Mg      |         194.|  1.374|   16.0|  |        |             |       |       |
|        |             |       |       |  |        |             |       |       |
|---------------------------------------|  |---------------------------------------|

Specific gravity       1.0230 @   25. C   Refractive Index      1.33860 @   25. C
PH                       8.00 @   25. C   Resistivity ohm/m     0.19800 @   25. C
Hydrogen Sulfide Description:
Organics Description            :
Calculated sodium:          12066.        Calculated TDS :             33431.
TDS by Evapor. @ 110 C:          34250.   TDS at Ignition :                31360.

Sample appearance:

THE ANALYSIS DETERMINED ON SALTY WATER EXTRACTED FROM OIL FLECKED WATERY MUD.

Remarks:

FE PRES. E83-14182-1: TOP RESIS: 1.23, MUD. -3: DHS RESIS: .200, LYNES UNITED
DHS #101 REC'D UNDER ATM. PRESSURE. RECOVERED FROM THE CHAMBER WAS 700 ML OIL
STAINED WATERY MUD. SUFFICIENT OIL COULD NOT BE REC'D FOR ANY ANALYSIS. BOTH R
ESIS OHM/M @ 25 C.
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                | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      80748    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     44552

CHEMICAL & GEOLOGICAL LAB LTD                     Lab. Sample ID. C78-3515-3

                                                         KB elev. Gr. elev
Well identifier  Well name
0515040805000    ANDEX ET AL HIGHVALE 5-8-51-4             757.30    753.20

Interval Sampled from:    1927.56  to:    1935.18 meters KB

Formation Sampled: WINT.

Sample produced by: DST #     1                   Sampling point:BOTTOM
  DST Recovery
        94.50 M    MUD
        72.90 M    WATER
        91.40 M    SULPHUROUS SALT WATER
 Date:    Sampled:  1978/06/16  Received: 1978/08/14  Analyzed: 1978/08/23

                 CATIONS                                   ANIONS
|---------------------------------------|  |---------------------------------------|
|  ION   |     mg/l     | %MEQ   | MEQ/L |  |  ION   |     mg/l     | %MEQ   | MEQ/L |
|---------------------------------------|  |---------------------------------------|
|Na+K    |       44176.|       |       |  |Cl      |       87400.| 79.905| 2465.2|
|Ca      |        8909.| 14.409|  444.6|  |HCO3    |         616.|  0.327|   10.1|
|Mg      |        1665.|  4.441|  137.0|  |SO4     |        1360.|  0.918|   28.3|
|        |             |       |       |  |        |             |       |       |
|---------------------------------------|  |---------------------------------------|

Specific gravity       1.1010 @   16. C   Refractive Index      1.35740 @   25. C
PH                       8.00 @   22. C   Resistivity ohm/m     0.06900 @   25. C
Hydrogen Sulfide Description:
Organics Description            :
Calculated sodium:          44194.        Calculated TDS :            143831.
TDS by Evapor. @ 110 C:         165500.   TDS at Ignition :               137400.

Sample appearance:

PALE YELLOW FILTRATE REC'D FROM A SAMPLE CONTAINING APPROX. 10% SED. AND H2S.

Remarks:

FE TRACE.
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    138171    Chemistry number:    5
AGSWDB Hard copy number   (HRDCPNO): -1730512

AGAT ENGINEERING LTD                          Lab. Sample ID. W2583

Well identifier  Well name                                KB elev. Gr. elev
0495052614000    AMOCO PEMBINA 14-26-49-5                   792.10    788.30

Interval Sampled from:    1738.00  to:    1743.00 meters KB

Formation Sampled: NORD

Sample produced by:                           Sampling point:SEPARATOR
 Date:   Sampled:  1985/12/24  Received: 1985/12/30  Analyzed: 1986/01/06

                 CATIONS                                     ANIONS
|-------------------------------------|   |-------------------------------------|
|  ION   |      mg/l     | %MEQ  | MEQ/L |   |  ION   |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na      |        22200.| 44.333|  965.6|   |Cl      |        39300.| 50.892| 1108.5|
|K       |          343.|  0.403|    8.8|   |HCO3    |         1020.|  0.767|   16.7|
|Ca      |         1090.|  2.497|   54.4|   |SO4     |          135.|  0.129|    2.8|
|Mg      |          207.|  0.782|   17.0|   |        |              |       |       |
|Fe      |          120.|  0.197|    4.3|   |        |              |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity       1.0460 @   0. C
PH                       6.70 @  25. C   Resistivity ohm/m     0.12000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:          24293.       Calculated TDS :            65527.

Sample appearance:

REFRACTIVE INDEX,BR, BA, SR AND I=N.A. N.A.=NOT ANALYZED. NIL=0.0. TRC+ = LESS
 THAN 0.1. TRC* = LESS THAN 0.001. SALINITY = 6.78%. N.D. = NOT DETECTED.
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    138171    Chemistry number:    6
AGSWDB Hard copy number   (HRDCPNO): -1731101

AGAT ENGINEERING LTD                          Lab. Sample ID. W2608

Well identifier  Well name                                KB elev. Gr. elev
0495052614000    AMOCO PEMBINA 14-26-49-5                   792.10    788.30

Interval Sampled from:    1738.00  to:    1743.00 meters KB

Formation Sampled: NORD

Sample produced by:                           Sampling point:DOME BATTERY 16-
 Date:   Sampled:  1985/12/30  Received: 1986/01/06  Analyzed: 1986/01/07

                 CATIONS                                     ANIONS
|-------------------------------------|   |-------------------------------------|
|  ION   |      mg/l     | %MEQ  | MEQ/L |   |  ION   |      mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na      |         3880.| 46.910|  168.8|   |Cl      |         5540.| 43.434|  156.3|
|K       |           27.|  0.194|    0.7|   |HCO3    |         1670.|  7.607|   27.4|
|Ca      |           61.|  0.849|    3.1|   |SO4     |            3.|  0.016|    0.1|
|Mg      |           30.|  0.686|    2.5|   |CO3     |           32.|  0.292|    1.0|
|Fe      |            1.|  0.012|    0.0|   |        |              |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity       1.0080 @   0. C
PH                       8.20 @  25. C   Resistivity ohm/m     0.54000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:           4120.       Calculated TDS :            10607.

Sample appearance:

REFRACTIVE INDEX,BR, BA, SR AND I=N.A. N.A.=NOT ANALYZED. NIL=0.0. TRC+ = LESS
 THAN 0.1. TRC* = LESS THAN 0.001. SALINITY = 0.99%. N.D. = NOT DETECTED.
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    138182    Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):  -1856306

CHEMICAL & GEOLOGICAL LAB LTD                 Lab. Sample ID. E86-1961-3

Well identifier  Well name                             KB elev. Gr. elev
0495053514000    ENRON ET AL PEMBINA 14-35-49-5           763.10    758.30

Interval Sampled from:   1706.00  to:   1715.50 meters KB

Formation Sampled: JUR SYS

Sample produced by: DST #    1                Sampling point:TOP OF TOOL
  DST Recovery
         54.00 M    GAS-CUT OIL
          6.00 M    WATER
 Date:    Sampled:  1986/12/04  Received: 1986/12/08  Analyzed: 1986/12/17

                CATIONS                                  ANIONS
|-------------------------------------|  |-------------------------------------|
| ION   |     mg/l     | %MEQ  | MEQ/L |  | ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na     |       18200.| 45.464|  791.7|  |Cl     |       30250.| 49.001|  853.2|
|K      |         236.|  0.347|    6.0|  |HCO3   |        1076.|  1.013|   17.6|
|Ca     |         685.|  1.963|   34.2|  |SO4    |         479.|  0.573|   10.0|
|Mg     |         347.|  1.640|   28.6|  |       |             |       |       |
|       |             |       |       |  |       |             |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity      1.0310 @  25. C    Refractive Index      1.34100 @  25. C
PH                      7.40 @  21. C    Resistivity ohm/m     0.14200 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:          18810.       Calculated TDS :          51100.
TDS by Evapor. @ 110 C:         49940.   TDS at Ignition :               47600.

Sample appearance:

ORGANICS: TRACE.SAMPLE CONSISTED OF VERY SLIGHTLY MUDDY SALT WATER.

Remarks:

Fe TRACE
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    138182    Chemistry number:    3
AGSWDB Hard copy number   (HRDCPNO):  -1856308

CHEMICAL & GEOLOGICAL LAB LTD                 Lab. Sample ID. E86-1962-2

Well identifier  Well name                             KB elev. Gr. elev
0495053514000    ENRON ET AL PEMBINA 14-35-49-5           763.10    758.30

Interval Sampled from:   1698.00  to:   1705.00 meters KB

Formation Sampled: ELRS

Sample produced by: DST #    2                Sampling point:DOWNHOLE SAMPLER
  DST Recovery
          6.00 M    GAS- AND OIL-CUT MUD
 Date:    Sampled:  1986/12/04  Received: 1986/12/08  Analyzed: 1986/12/17

                CATIONS                                  ANIONS
|-------------------------------------|  |-------------------------------------|
| ION   |     mg/l     | %MEQ  | MEQ/L |  | ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na     |       24090.| 45.743| 1047.9|  |Cl     |       40000.| 49.252| 1128.3|
|K      |         305.|  0.341|    7.8|  |HCO3   |         996.|  0.713|   16.3|
|Ca     |         969.|  2.111|   48.4|  |SO4    |         239.|  0.217|    5.0|
|Mg     |         452.|  1.624|   37.2|  |       |             |       |       |
|       |             |       |       |  |       |             |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity      1.0440 @  25. C    Refractive Index      1.34360 @  25. C
PH                      7.10 @  21. C    Resistivity ohm/m     0.11300 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:          24464.       Calculated TDS :          66613.
TDS by Evapor. @ 110 C:         65380.   TDS at Ignition :               62960.

Sample appearance:

ORGANICS: NIL. SAMPLE CONSISTED OF SALT WATER WITH A SLIGHT OIL SCUM.

Remarks:

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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    138171   Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):  -1730508

AGAT ENGINEERING LTD                         Lab. Sample ID. WE6082A

Well identifier  Well name                              KB elev. Gr. elev
0495052614000    AMOCO PEMBINA 14-26-49-5                  792.10    788.30

Interval Sampled from:   1747.00  to:   1752.00 meters KB

Formation Sampled: BNFF

Sample produced by: DST #    1                 Sampling point:BHS 197
  DST Recovery
        2.00 M   MUD
 Date:  Sampled:  1985/11/02  Received: 1985/11/07  Analyzed: 1985/11/11

                 CATIONS                                   ANIONS
|-------------------------------------|   |-------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |   |  ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na      |          818.| 51.309|   35.6|   |Cl      |          362.| 14.724|   10.2|
|K       |           11.|  0.406|    0.3|   |HCO3    |          924.| 21.837|   15.1|
|Ca      |            5.|  0.381|    0.3|   |SO4     |          238.|  7.146|    5.0|
|Mg      |            1.|  0.154|    0.1|   |CO3     |           84.|  4.037|    2.8|
|Fe      | 0.10000      |  0.005|    0.0|   |        |              |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity       1.0020 @   0. C
PH                       9.90 @  25. C   Resistivity ohm/m    2.88000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:           753.        Calculated TDS :          1898.

Sample appearance:

BR,SR,BR,I & RE. INDEX=N.A.NIL=0.0.TRC+ = LESS THAN 0.1. TRC* = LESS THAN 0.00
1. SALINITY:0.07%. THE "30 MIN" API MUD FILTRATE LOSS IS 10 MLS. THE ABOVE RES
ULTS PERTAIN TO THE WATER EXTRACTED FROM MUD. DST CHAMBER O.P. = 0 KPA RECOVER
Y = 1 LITRE MUD SALINITY = 0.07%
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    138171   Chemistry number:    2
AGSWDB Hard copy number   (HRDCPNO):  -1730509

AGAT ENGINEERING LTD                         Lab. Sample ID. WE6082B

Well identifier  Well name                              KB elev. Gr. elev
0495052614000    AMOCO PEMBINA 14-26-49-5                  792.10    788.30

Interval Sampled from:   1721.00  to:   1736.50 meters KB

Formation Sampled: BSL QTZ

Sample produced by: DST #    3                 Sampling point:BHS 158
  DST Recovery
       13.50 M   MUD
 Date:  Sampled:  1985/11/04  Received: 1985/11/07  Analyzed: 1985/11/11

                 CATIONS                                   ANIONS
|-------------------------------------|   |-------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |   |  ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na      |          802.| 51.465|   34.9|   |Cl      |          625.| 26.008|   17.6|
|K       |            9.|  0.336|    0.2|   |HCO3    |          476.| 11.509|    7.8|
|Ca      |            3.|  0.221|    0.1|   |SO4     |          164.|  5.037|    3.4|
|Mg      | 0.90000      |  0.109|    0.1|   |CO3     |          108.|  5.310|    3.6|
|Fe      | 0.10000      |  0.005|    0.0|   |        |              |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity       1.0020 @   0. C
PH                       9.30 @  25. C   Resistivity ohm/m    2.67000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:           741.        Calculated TDS :          1876.

Sample appearance:

BR, BA, SR ,REF. INDEX AND I=N.A.N.A.=NOT ANALYZED. TRC+ = LESS THAN 0.1. TRC*
 = LESS THAN 0.001. SALINITY = 0.12%. THE "30 MIN" API MUD FILTRATE LOSS IS 10
MLS. THE ABOVE RESULTS PERTAIN TO THE WATER EXTRACTED FROM THE MUD. DST CHAMBE
R O.P. = 0 KPA RECOVERY = 2 LITRES MUD. SALINITY = 0.12%
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    138171    Chemistry number:    3
AGSWDB Hard copy number    (HRDCPNO):  -1730510

AGAT ENGINEERING LTD                             Lab. Sample ID. W2593

Well identifier  Well name                                 KB elev. Gr. elev
0495052614000    AMOCO PEMBINA 14-26-49-5                     792.10    788.30

Interval Sampled from:   1738.00  to:   1743.00 meters KB

Formation Sampled: NORD

Sample produced by:                              Sampling point:SIGHT GLASS
 Date:   Sampled:  1985/12/30  Received: 1985/12/31  Analyzed: 1986/01/06

                 CATIONS                                  ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION   |     mg/l      | %MEQ  | MEQ/L |  |  ION   |     mg/l      | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na      |        26900.| 45.182| 1170.1|  |Cl      |        46500.| 50.647| 1311.6|
|K       |          377.|  0.372|    9.6|  |HCO3    |          793.|  0.502|   13.0|
|Ca      |         1240.|  2.389|   61.9|  |SO4     |          144.|  0.116|    3.0|
|Mg      |          238.|  0.756|   19.6|  |        |              |       |       |
|Fe      |           26.|  0.036|    0.9|  |        |              |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity       1.0470 @   0. C
PH                       6.50 @  25. C   Resistivity ohm/m    0.11000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:        28651.         Calculated TDS :          77163.

Sample appearance:

BR, BA, SR,REF. INDEX AND I=N.A. N.A.=NOT ANALYZED.NIL=0.0. TRC+ = LESS THAN 0
.1. TRC* = LESS THAN 0.001. SALINITY = 8.02%. N.D. = NOT DETECTED.
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    138171    Chemistry number:    4
AGSWDB Hard copy number    (HRDCPNO):  -1730511

AGAT ENGINEERING LTD                             Lab. Sample ID. W2573

Well identifier  Well name                                 KB elev. Gr. elev
0495052614000    AMOCO PEMBINA 14-26-49-5                     792.10    788.30

Interval Sampled from:   1738.00  to:   1743.00 meters KB

Formation Sampled: NORD

Sample produced by:                              Sampling point:RIG TANK
 Date:   Sampled:  1985/12/22  Received: 1985/12/27  Analyzed: 1986/01/02

                 CATIONS                                  ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION   |     mg/l      | %MEQ  | MEQ/L |  |  ION   |     mg/l      | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na      |        20000.| 45.363|  870.0|  |Cl      |        34200.| 50.302|  964.7|
|K       |          269.|  0.359|    6.9|  |HCO3    |          888.|  0.759|   14.6|
|Ca      |          898.|  2.337|   44.8|  |SO4     |          157.|  0.170|    3.3|
|Mg      |          165.|  0.708|   13.6|  |        |              |       |       |
|Fe      |  1.0000      |  0.002|    0.0|  |        |              |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity       1.0380 @   0. C
PH                       7.60 @  25. C   Resistivity ohm/m    0.12000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:        21246.         Calculated TDS :          57103.

Sample appearance:

BR, BA, SR,REFRACTIVE INDEX AND I=N.A. N.A.=NOT ANALYZED.NIL=0.0. TRC+ = LESS
THAN 0.1. TRC* = LESS THAN 0.001. SALINITY = 5.94%. N.D. = NOT DETECTED.
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| AGSWDB WATER ANALYSIS REPORT |

AGSWDB Well site identifier (SITID): 138155 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): -1843306

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E86-1499-4

Well identifier	Well name	KB elev.	Gr. elev
0495043406000	ANDEX ET AL PEMBINA 6-34-49-4	785.10	780.30

Interval Sampled from: 1645.00 to: 1659.00 meters KB

Formation Sampled: BNFF

Sample produced by: DST # 1 Sampling point:DOWNHOLE SAMPLER
DST Recovery
23.00 M MUD
25.00 M GAS- AND OIL-CUT MUD
32.00 M BRACKISH WATER-CUT MUD
Date: Sampled: 1986/11/21 Received: 1986/11/25 Analyzed: 1986/12/04

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	12320.	45.410	535.9
K	167.	0.362	4.3
Ca	573.	2.423	28.6
Mg	255.	1.778	21.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	20200.	48.281	569.8
HCO3	615.	0.854	10.1
SO4	506.	0.893	10.5

Specific gravity 1.0220 @ 25. C
PH 7.40 @ 23. C
Refractive Index 1.33860 @ 25. C
Resistivity ohm/m 0.19900 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 12434.
Calculated TDS : 34271.
TDS by Evapor. @ 110 C: 33680.
TDS at Ignition : 32590.

Sample appearance:

ORGANICS: MUCH. A MCALLISTER PETRO IND. DOWNHOLE SAMPLER WAS RECEIVED AT 689 KPA. IT CONTAINED GAS AND 1300 ML OF OIL STAINED WATERY MUD. ANALYSIS PERFORMED ON SALT WATER EXTRACTED FROM THE MUD.

Remarks:

Fe MUCH [E86-1499-1]:SAMPLED FROM TOP|RESISTIVITY: 3.33 OHM METERS @ 25 C.|SAMPLE CONSISTED OF MUD.|[E86-1499-2]:SAMPLED FROM MIDDLE.|RESISTIVITY:0.448 OHM METERS @ 25 C.|SAMPLE CONSISTED OF MUD.|[E86-1499-3]:SAMPLED FROM TOP OF TOOL|RESISTIVITY:0 .225 OHM METERS @ 25 C.|SAMPLE CONSISTED OF SLIGHTLY OIL FLECKED WATERY MUD.

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| AGSWDB WATER ANALYSIS REPORT |

AGSWDB Well site identifier (SITID): 138155 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): -1843308

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E86-1500-1

Well identifier	Well name	KB elev.	Gr. elev
0495043406000	ANDEX ET AL PEMBINA 6-34-49-4	785.10	780.30

Interval Sampled from: 1640.00 to: 1644.00 meters KB

Formation Sampled: NORD

Sample produced by: DST # 2 Sampling point:TOP OF TOOL
DST Recovery
10.00 M OIL-CUT MUD
Date: Sampled: 1986/11/21 Received: 1986/11/25 Analyzed: 1986/12/04

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	4810.	45.080	209.2
K	60.	0.331	1.5
Ca	146.	1.570	7.3
Mg	62.	1.099	5.1

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	7800.	47.404	220.0
HCO3	730.	2.578	12.0
SO4	432.	1.938	9.0

Specific gravity 1.0040 @ 25. C
PH 8.20 @ 23. C
Refractive Index 1.33500 @ 25. C
Resistivity ohm/m 0.47500 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 5255.
Calculated TDS : 14054.
TDS by Evapor. @ 110 C: 13590.
TDS at Ignition : 12940.

Sample appearance:

ORGANICS:MUCH. SAMPLE ANALYSED CONSISTED OF SLIGHTLY SALTY WATER EXTRACTED FROM SLIGHTLY OIL FLECKED MUD.

Remarks:

Fe TRACE

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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 138155 Chemistry number: 4
AGSWDB Hard copy number (HRDCPNO): -1843311

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E86-1496-4

Well identifier	Well name	KB elev.	Gr. elev
0495043406000	ANDEX ET AL PEMBINA 6-34-49-4	785.10	780.30

Interval Sampled from: 1639.20 to: 1644.00 meters KB

Formation Sampled: NORD

Sample produced by: DST # 4 Sampling point:DOWN HOLE SAMPLE
DST Recovery
40.00 M GAS- AND OIL-CUT MUD
Date: Sampled: 1986/11/23 Received: 1986/11/25 Analyzed: 1986/11/28

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	4490.	44.373	195.3
K	58.	0.337	1.5
Ca	218.	2.472	10.9
Mg	79.	1.477	6.5

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	7090.	45.436	200.0
HCO3	839.	3.124	13.8
SO4	588.	2.782	12.2

Specific gravity 1.0090 @ 25. C
PH 8.20 @ 23. C
Refractive Index 1.33550 @ 25. C
Resistivity ohm/m 0.47700 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 4796.
Calculated TDS : 13184.
TDS by Evapor. @ 110 C: 13260.
TDS at Ignition : 12470.

Sample appearance:

BAKER OIL TOOLS DOWNHOLE SAMPLER 119 RECEIVED UNDER ATMOSPHERIC PRESSURE. CONTAINED IN THE CHAMBER WAS 500 ML OF WATERY MUD AND OIL (40% OIL). ANALYSIS DETERMINED ON SLIGHTLY SALTY WATER EXTRACTED FROM THE MUD.

Remarks:

Fe TRACE [E86-1496-1]:SAMPLED FROM TOP|RESISTIVITY:2.54 OHM METER @ 25 C.| SAMPLE CONSISTED OF SLIGHTLY OIL STAINED MUD.|[E86-1496-2]:SAMPLED FROM MIDDLE|RESISTIVITY:2.26 OHM METERS @ 25 C.|SAMPLE CONSISTED OF SLIGHTLY OIL STAINED MUD.|[E86-1496-3]: SAMPLED FROM BOTTOM|RESISTIVITY:0.976 OHM METERS @ 25 C.|SAMPLE CONSISTED OF OIL STAINED MUD. (12% OIL).

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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 138170 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): -1876511

GEOTECH Analytical Lab. Sample ID. 5212-W1

Well identifier	Well name	KB elev.	Gr. elev
0495052411000	COLGAS PEMBINA 11-24-49-5	804.40	799.70

Interval Sampled from: 1742.00 to: 1754.00 meters KB

Formation Sampled: BNFF

Sample produced by: DST # 4 Sampling point:TOP OF TOOL
DST Recovery
25.00 M MUD
300.00 M MUD-CUT WATER
Date: Sampled: 1987/02/27 Received: 1987/03/03 Analyzed: 1987/03/05

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	930.	48.421	40.5
K	13.	0.389	0.3
Ca	4.	0.245	0.2
Mg	0.41000	0.040	0.0
Fe	3.	0.107	0.1

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	343.	11.581	9.7
HCO3	616.	12.084	10.1
SO4	863.	21.508	18.0
CO3	141.	5.625	4.7

Other Determinations

Parameter	mg/l
barium	0.24000
boron	0.65000
strontium	0.34000

Refractive Index 1.34500 @ 0. C
PH 8.20 @ 25. C
Resistivity ohm/m 2.70300 @ 25. C
Calculated sodium: 970.
Calculated TDS : 2625.

Sample appearance:

B-0.649. I-<1.00 CATIONS/ANIONS: 0.97.

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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 82310 Chemistry number: 6
AGSWDB Hard copy number (HRDCPNO): 43888

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. 8327-9

Well identifier	Well name	KB elev.	Gr. elev
0525051816000	IMP CDN-SUP TOMAHAWK 16-18-52-5	799.80	795.20

Interval Sampled from: 1976.32 to: 1988.52 meters KB

Formation Sampled: GRAMINIA

Sample produced by: DST # 9 Sampling point:DST #9
DST Recovery
103.60 M MUD-CUT SULPHUROUS SALT WATER
Date: Sampled: 1956/04/14 Analyzed: 1956/06/14

CATIONS

ION	mg/l	%MEQ	MEQ/L
Ca	10603.	18.558	529.1
Mg	560.	1.616	46.1

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	79440.	78.595	2240.7
HCO3	150.	0.086	2.5
SO4	1522.	1.112	31.7
CO3	28.	0.033	0.9

Specific gravity 1.0900 @ 16. C
PH 7.70 @ 0. C
Organics Description :
Calculated sodium: 39102.

Resistivity ohm/m 0.07900 @ 20. C

Calculated TDS : 131329.
TDS at Ignition : 129150.

Remarks:

PRI. SAL. 74.72, SECOND. SAL. 25.14, SECOND. ALKALI. .14, CL SAL. 98.60, SO4 SAL. 1.40

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 82310 Chemistry number: 7
AGSWDB Hard copy number (HRDCPNO): 43889

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. 8327-10

Well identifier	Well name	KB elev.	Gr. elev
0525051816000	IMP CDN-SUP TOMAHAWK 16-18-52-5	799.80	795.20

Interval Sampled from: 2694.43 to: 2708.15 meters KB

Formation Sampled: ELK POINT

Sample produced by: DST # 10 Sampling point:DST #10
DST Recovery
246.90 M SALT WATER
Date: Sampled: 1956/05/19 Analyzed: 1956/06/14

CATIONS

ION	mg/l	%MEQ	MEQ/L
Ca	26277.	24.200	1311.2
Mg	1680.	2.551	138.2

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	140013.	72.887	3949.3
HCO3	110.	0.033	1.8
SO4	811.	0.312	16.9
CO3	28.	0.017	0.9

Specific gravity 1.1520 @ 16. C
PH 7.30 @ 0. C
Organics Description :
Calculated sodium: 57930.

Resistivity ohm/m 0.05570 @ 20. C

Calculated TDS : 226793.
TDS at Ignition : 221460.

Remarks:

PRI. SAL. 63.48, SECOND. SAL. 36.44, SECOND. ALKALI. .08, CL SAL. 99.58, SO4 SAL. .42

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 82310 Chemistry number: 8
AGSWDB Hard copy number (HRDCPNO): 43890

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. 8327-11

Well identifier	Well name	KB elev.	Gr. elev
0525051816000	IMP CDN-SUP TOMAHAWK 16-18-52-5	799.80	795.20

Interval Sampled from: 2753.87 to: 2769.11 meters KB

Formation Sampled: ELK POINT

Sample produced by: DST # 11 Sampling point:DST #11
DST Recovery
91.40 M MUD-CUT SALT WATER

CATIONS

ION	mg/l	%MEQ	MEQ/L
Ca	26277.	24.230	1311.2
Mg	1540.	2.342	126.7

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	140013.	72.978	3949.3
HCO3	138.	0.042	2.3
SO4	1016.	0.391	21.2
CO3	28.	0.017	0.9

Specific gravity 1.1520 @ 16. C
PH 7.90 @ 0. C
Resistivity ohm/m 0.05550 @ 20. C
Organics Description :
Calculated sodium: 58304.
Calculated TDS : 227246.
TDS at Ignition : 220960.

Remarks:

PRI. SAL. 63.80, SECOND. SAL. 36.12, SECOND. ALKALI. .08, CL SAL. 99.46, SO4 SAL. .54

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 82314 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 43891

CORE LABORATORIES CANADA LT. Lab. Sample ID. 7021-31875

Well identifier	Well name	KB elev.	Gr. elev
0525052105000	AMOCO A-1 TOMAHAWK 5-21-52-5	786.10	782.10

Interval Sampled from: 1622.15 to: 1631.59 meters KB

Formation Sampled: BASAL QUARTZ

Sample produced by: DST # 2 Sampling point:BOTTOM
DST Recovery
45.70 M WATER-CUT MUD
Date: Sampled: 1973/12/07 Received: 1973/12/18 Analyzed: 1973/12/23

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na+K	9377.		
Ca	356.	3.943	17.8
Mg	44.	0.804	3.6

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	14695.	91.993	414.5
HCO3	781.	2.841	12.8
SO4	91.	0.421	1.9

Specific gravity 1.0175 @ 16. C
PH 7.50 @ 0. C
Refractive Index 1.33610 @ 24. C
Resistivity ohm/m 0.24900 @ 25. C
Hydrogen Sulfide Description:
Calculated sodium: 9376.
Calculated TDS : 24946.

Remarks:

FE TRACE.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 82307 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 43878

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. C81-6414-4

Well identifier	Well name	KB elev.	Gr. elev
0525051801000	COLGAS TOMAHAWK 1-18-52-5	802.90	799.20

Interval Sampled from: 1640.00 to: 1650.00 meters KB

Formation Sampled: BANFF

Sample produced by: DST # 1 Sampling point:BOTTOM
DST Recovery
156.00 M GAS- AND OIL-CUT MUD
Date: Sampled: 1981/01/13 Received: 1981/01/19 Analyzed: 1981/01/30

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	9146.	44.610	397.8
K	164.	0.470	4.2
Ca	561.	3.139	28.0
Mg	207.	1.910	17.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	15130.	47.855	426.8
HCO3	769.	1.413	12.6
SO4	258.	0.602	5.4

Specific gravity 1.0160 @ 25. C
PH 7.50 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 9190.
TDS by Evapor. @ 110 C: 30410.

Refractive Index 1.33760 @ 25. C
Resistivity ohm/m 0.25400 @ 25. C
Calculated TDS : 25724.
TDS at Ignition : 22140.

Sample appearance:

PALE YELLOW FILTRATE REC'D FROM A SAMPLE CONTAINING APPROX. 50% SED. AND A LAYER OF HYDRO.

Remarks:

FE TRACE. C81-6414-2 TOP RESIS: 1.56, PALE YELLOW FILTRATE REC'D FROM THE WATER PORTION OF THE SAMPLE. -3: MID RESIS: .473, SAME AS -2. BOTH RESIS OHM/M @ 25 C.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 82308 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 43879

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E82-10675-2

Well identifier	Well name	KB elev.	Gr. elev
0525051806000	COLGAS ET AL SUNDANCE 6-18-52-5	820.90	816.50

Interval Sampled from: 1656.00 to: 1666.00 meters KB

Formation Sampled: NORD 4440

Sample produced by: DST # 1 Sampling point:MIDDLE
DST Recovery
60.00 M OIL-CUT MUD
Date: Sampled: 1982/12/29 Received: 1982/01/05 Analyzed: 1982/01/26

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	1332.	46.782	57.9
K	14.	0.289	0.4
Ca	36.	1.450	1.8
Mg	22.	1.462	1.8

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	1475.	33.593	41.6
HCO3	689.	9.117	11.3
SO4	377.	6.338	7.8
CO3	36.	0.969	1.2

Specific gravity 1.0030 @ 25. C
PH 9.10 @ 19. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 1341.
TDS by Evapor. @ 110 C: 4040.

Refractive Index 1.33410 @ 25. C
Resistivity ohm/m 1.78000 @ 25. C
Calculated TDS : 3626.
TDS at Ignition : 2660.

Sample appearance:

THE SAMPLE CONSISTED OF MUDDY WATER WITH A TRACE OF OIL.

Remarks:

FE PRES.

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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     82310    Chemistry number:    2
AGSWDB Hard copy number   (HRDCPNO):     43884

CHEMICAL & GEOLOGICAL LAB LTD                    Lab. Sample ID. 8327-2

Well identifier  Well name                                KB elev. Gr. elev
0525051816000    IMP CDN-SUP TOMAHAWK 16-18-52-5            799.80    795.20

Interval Sampled from:   1565.45  to:   1576.12 meters KB

Formation Sampled: BLAIRMORE

Sample produced by: DST #    3                   Sampling point:
  DST Recovery
        61.00 M   MUD
       102.10 M   SALT WATER
 Date:   Sampled:  1956/03/21                          Analyzed: 1956/06/14

                 CATIONS                                      ANIONS
|------------------------------------|    |------------------------------------|
|  ION  |      mg/l     | %MEQ | MEQ/L |    |  ION  |      mg/l     | %MEQ | MEQ/L |
|------------------------------------|    |------------------------------------|
|Ca     |           318.| 2.298|   15.9|    |Cl     |         22094.|90.246|  623.2|
|Mg     |           132.| 1.573|   10.9|    |HCO3   |           615.| 1.460|   10.1|
|       |               |      |       |    |SO4    |           257.| 0.775|    5.4|
|       |               |      |       |    |CO3    |           756.| 3.649|   25.2|
|       |               |      |       |    |       |               |      |       |
|------------------------------------|    |------------------------------------|

Specific gravity        1.0270 @  16. C
PH                       11.40 @   0. C    Resistivity ohm/m    0.18900 @  20. C
Organics Description          :
Calculated sodium:        14648.           Calculated TDS :           38507.
                                           TDS at Ignition :               37290.

Remarks:

PRI. SAL. 94.68, PRI. ALKALI. 1.30, SECOND. ALKALI. 4.02, CL SAL. 99.16, SO4 S
AL. .84
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     82310    Chemistry number:    5
AGSWDB Hard copy number   (HRDCPNO):     43887

CHEMICAL & GEOLOGICAL LAB LTD                    Lab. Sample ID. 8327-8

Well identifier  Well name                                KB elev. Gr. elev
0525051816000    IMP CDN-SUP TOMAHAWK 16-18-52-5            799.80    795.20

Interval Sampled from:   1822.70  to:   1836.42 meters KB

Formation Sampled: WABAMUN

Sample produced by: DST #    8                   Sampling point:DST #8
  DST Recovery
      804.70 M   MUD-CUT SULPHUROUS SALT WATER
 Date:   Sampled:  1956/04/09                          Analyzed: 1956/06/14

                 CATIONS                                      ANIONS
|------------------------------------|    |------------------------------------|
|  ION  |      mg/l     | %MEQ | MEQ/L |    |  ION  |      mg/l     | %MEQ | MEQ/L |
|------------------------------------|    |------------------------------------|
|Ca     |         12678.|17.423|  632.6|    |Cl     |        100293.|77.908| 2828.9|
|Mg     |          1820.| 4.124|  149.8|    |HCO3   |           315.| 0.142|    5.2|
|       |               |      |       |    |SO4    |           551.| 0.316|   11.5|
|       |               |      |       |    |CO3    |            95.| 0.087|    3.2|
|       |               |      |       |    |       |               |      |       |
|------------------------------------|    |------------------------------------|

Specific gravity        1.1140 @  16. C
PH                        6.60 @   0. C    Resistivity ohm/m    0.06800 @  20. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:        47511.           Calculated TDS :          163103.
                                           TDS at Ignition :              158120.

Remarks:

PRI. SAL. 72.54, SECOND. SAL. 27.16, SECOND. ALKALI. .30, CL SAL. 99.60, SO4 S
AL. .40
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                     | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      80828    Chemistry number:    2
AGSWDB Hard copy number    (HRDCPNO):     44632

CHEMICAL & GEOLOGICAL LAB LTD                 Lab. Sample ID. E77-8828-2

Well identifier  Well name                                KB elev. Gr. elev
0515043411000    COLGAS ET AL HIGHVALE 11-34-51-4            789.70    785.80

Interval Sampled from:   1542.90   to:   1555.09 meters KB

Formation Sampled: NORDEGG

Sample produced by: DST #    3                 Sampling point:MIDDLE
  DST Recovery
        97.50 M   GAS-CUT MUD
 Date:    Sampled:  1977/08/09  Received: 1977/08/12  Analyzed: 1977/08/23

                CATIONS                                  ANIONS
|-------------------------------------|   |-------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |   |  ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na      |        6092.| 45.136|  265.0|   |Cl      |        9780.| 46.987|  275.9|
|Ca      |         275.|  2.337|   13.7|   |HCO3    |         725.|  2.024|   11.9|
|Mg      |         180.|  2.523|   14.8|   |SO4     |         280.|  0.993|    5.8|
|        |             |       |       |   |        |             |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity      1.0140 @  16. C   Refractive Index     1.33650 @  25. C
PH                      7.40 @  24. C   Resistivity ohm/m    0.38700 @  25. C
Hydrogen Sulfide Description:
Organics Description         :
Calculated sodium:         6094.        Calculated TDS :          16965.
TDS by Evapor. @ 110 C:         18305.  TDS at Ignition :              15889.

Sample appearance:

THE SAMPLE CONSISTED OF MUDDY WATER.

Remarks:

FE PRES. E77-8828-1 TOP RESIS: .396, MUDDY WATER. -3 BOTTOM RESIS: .479, MUD S
AMPLE. RESIS OHM/M @ 25 C.
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                     | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      80828    Chemistry number:    3
AGSWDB Hard copy number    (HRDCPNO):     44633

CHEMICAL & GEOLOGICAL LAB LTD                 Lab. Sample ID. E77-8829

Well identifier  Well name                                KB elev. Gr. elev
0515043411000    COLGAS ET AL HIGHVALE 11-34-51-4            789.70    785.80

Interval Sampled from:   1555.09   to:   1597.15 meters KB

Formation Sampled: BANFF

Sample produced by: DST #    5                 Sampling point:MIDDLE
  DST Recovery
      1365.50 M   SALT WATER
 Date:    Sampled:  1977/08/11  Received: 1977/08/12  Analyzed: 1977/08/23

                CATIONS                                  ANIONS
|-------------------------------------|   |-------------------------------------|
|  ION   |     mg/l     | %MEQ  | MEQ/L |   |  ION   |     mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|   |-------------------------------------|
|Na      |       27368.| 40.651| 1190.4|   |Cl      |       51200.| 49.315| 1444.2|
|Ca      |        3606.|  6.144|  179.9|   |HCO3    |        1079.|  0.604|   17.7|
|Mg      |        1139.|  3.200|   93.7|   |SO4     |         121.|  0.086|    2.5|
|        |             |       |       |   |        |             |       |       |
|-------------------------------------|   |-------------------------------------|

Specific gravity      1.0600 @  16. C   Refractive Index     1.34730 @  25. C
PH                      6.10 @  24. C   Resistivity ohm/m    0.10500 @  25. C
Hydrogen Sulfide Description:
Organics Description         :
Calculated sodium:        27378.        Calculated TDS :          83974.
TDS by Evapor. @ 110 C:         91300.  TDS at Ignition :              81380.

Sample appearance:

THE SAMPLE CONSISTED OF COLORLESS WATER WITH A LAYER OF MUD.

Remarks:

FE MUCH.
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      82303    Chemistry number:    1
AGSWDB Hard copy number   (HRDCPNO):      43872

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. E82-13879

Well identifier  Well name                               KB elev. Gr. elev
0525050716000    PCP TOMAHAWK 16-7-52-5                    799.80    796.00

Interval Sampled from:   1650.00  to:   1657.00 meters KB

Formation Sampled: NORDEGG

Sample produced by: DST #    1                Sampling point:DHS
  DST Recovery
       100.00 M   GAS- AND OIL-CUT MUD
 Date:   Sampled:  1982/03/01  Received: 1982/03/05  Analyzed: 1982/03/26

                 CATIONS                                  ANIONS
|------------------------------------|  |------------------------------------|
| ION  |      mg/l     | %MEQ  | MEQ/L |  | ION  |      mg/l     | %MEQ  | MEQ/L |
|------------------------------------|  |------------------------------------|
|Na    |        23783.| 41.715| 1034.5|  |Cl    |        43600.| 49.591| 1229.8|
|K     |          305.|  0.315|    7.8|  |HCO3  |          325.|  0.215|    5.3|
|Ca    |         2571.|  5.173|  128.3|  |SO4   |          239.|  0.201|    5.0|
|Mg    |          841.|  2.791|   69.2|  |      |              |       |       |
|      |              |       |       |  |      |              |       |       |
|------------------------------------|  |------------------------------------|

Specific gravity       1.0480 @  25. C   Refractive Index      1.34590 @  25. C
PH                       6.10 @  24. C   Resistivity ohm/m     0.10900 @  25. C
Hydrogen Sulfide Description:
Organics Description            :
Calculated sodium:        23972.         Calculated TDS :           71383.
TDS by Evapor. @ 110 C:        76260.    TDS at Ignition :              68400.

Sample appearance:

A LYNES UNITED DHS #89 REC'D AT ATM. PRESSURE. IT CONTAINED 2.3 L OF WATER ONL
Y.

Remarks:

FE PRESENT.
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      82303    Chemistry number:    2
AGSWDB Hard copy number   (HRDCPNO):      43873

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. E82-13618-3

Well identifier  Well name                               KB elev. Gr. elev
0525050716000    PCP TOMAHAWK 16-7-52-5                    799.80    796.00

Interval Sampled from:   1650.00  to:   1657.00 meters KB

Formation Sampled: NORDEGG

Sample produced by: DST #    1                Sampling point:BOTTOM
  DST Recovery
       100.00 M   GAS- AND OIL-CUT MUD
 Date:   Sampled:  1982/03/09  Received: 1982/03/11  Analyzed: 1982/03/25

                 CATIONS                                  ANIONS
|------------------------------------|  |------------------------------------|
| ION  |      mg/l     | %MEQ  | MEQ/L |  | ION  |      mg/l     | %MEQ  | MEQ/L |
|------------------------------------|  |------------------------------------|
|Na    |        21263.| 41.254|  924.9|  |Cl    |        39300.| 49.444| 1108.5|
|K     |          317.|  0.362|    8.1|  |HCO3  |          356.|  0.260|    5.8|
|Ca    |         2643.|  5.883|  131.9|  |SO4   |          325.|  0.302|    6.8|
|Mg    |          680.|  2.496|   56.0|  |      |              |       |       |
|      |              |       |       |  |      |              |       |       |
|------------------------------------|  |------------------------------------|

Specific gravity       1.0460 @  25. C   Refractive Index      1.34450 @  25. C
PH                       7.80 @  23. C   Resistivity ohm/m     0.13000 @  25. C
Hydrogen Sulfide Description:
Organics Description            :
Calculated sodium:        21458.         Calculated TDS :           64581.
TDS by Evapor. @ 110 C:        67820.    TDS at Ignition :              59420.

Sample appearance:

THE SAMPLE CONSISTED OF OIL STAINED MUDDY, SALT WATER.

Remarks:

FE PRES. E82-13618-1: TOP RESIS: 1.99, OIL STAINED MUD. -2; MIDDLE RESIS: .217
 OIL STAINED MUDDY WATER. BOTH RESIS OHM/M @ 25 C.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80826 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 44625

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. D77-2233-3

Well identifier	Well name	KB elev.	Gr. elev
0515042910000	COLGAS ET AL HIGHVALE 10-29-51-4	799.50	795.50

Interval Sampled from: 1621.54 to: 1639.82 meters KB

Formation Sampled: BANFF

Sample produced by: DST # 1 Sampling point:BOTTOM
DST Recovery
56.40 M MUD
91.40 M GAS- AND OIL-CUT MUD
61.00 M OIL- AND WATER-CUT MUD
Date: Sampled: 1977/11/15 Received: 1977/11/18 Analyzed: 1977/12/02

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	33096.	44.691	1439.6
Ca	2140.	3.315	106.8
Mg	778.	1.987	64.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	56400.	49.387	1590.8
HCO3	862.	0.439	14.1
SO4	280.	0.181	5.8

Specific gravity 1.0660 @ 16. C
PH 7.50 @ 21. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 33108.
TDS by Evapor. @ 110 C: 101680.

Refractive Index 1.34860 @ 25. C
Resistivity ohm/m 0.09400 @ 25. C
Calculated TDS : 93130.
TDS at Ignition : 87560.

Sample appearance:

THE SAMPLE CONSISTED OF MUDDY WATER.

Remarks:

FE PRES. D77-2233-1 TOP RESIS; .253, MUD SAMPLE. -2 MID RESIS; .121, WATERY MUD SAMPLE. BOTH RESIS OHM/M @ 25 C.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80826 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): 44626

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. D77-2234-3

Well identifier	Well name	KB elev.	Gr. elev
0515042910000	COLGAS ET AL HIGHVALE 10-29-51-4	799.50	795.50

Interval Sampled from: 1582.52 to: 1606.30 meters KB

Formation Sampled: BANFF

Sample produced by: DST # 2 Sampling point:BOTTOM
DST Recovery
61.00 M GAS- AND OIL-CUT MUD
667.50 M GAS-CUT SALT WATER
243.80 M OIL- AND GAS-CUT SALT WATER
Date: Sampled: 1977/11/15 Received: 1977/11/18 Analyzed: 1977/12/02

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	30673.	44.073	1334.2
Ca	2372.	3.910	118.4
Mg	740.	2.011	60.9

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	53100.	49.476	1497.8
HCO3	735.	0.398	12.0
SO4	191.	0.131	4.0

Specific gravity 1.0620 @ 16. C
PH 6.80 @ 21. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 30684.
TDS by Evapor. @ 110 C: 93980.

Refractive Index 1.34820 @ 25. C
Resistivity ohm/m 0.09800 @ 25. C
Calculated TDS : 87448.
TDS at Ignition : 82820.

Sample appearance:

THE SAMPLE CONSISTED OF MURKY WATER.

Remarks:

FE PRES. D77-2234-1 TOP RESIS: .192, VERY MUDDY WATER. -2 MIDDLE RESIS: .107, MUDDY WATER. BOTH RESIS OHM/M @ 25 C.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80827 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 44628

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E78-3618-5

Well identifier	Well name	KB elev.	Gr. elev
0515043401000	ANDEX ET AL HIGHVALE 1-34-51-4	802.20	798.10

Interval Sampled from: 1948.00 to: 1956.00 meters KB

Formation Sampled: WINT.

Sample produced by: DST # 1 Sampling point:BOTTOM
DST Recovery
60.00 M MUD
280.00 M GAS-CUT MUD
1320.00 M GAS-CUT SALT WATER
Date: Sampled: 1978/11/13 Received: 1978/11/15 Analyzed: 1978/11/29

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na+K	48818.		
Ca	11490.	15.514	573.4
Mg	2582.	5.749	212.5

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	102500.	78.231	2891.2
HCO3	437.	0.194	7.2
SO4	553.	0.312	11.5

Specific gravity 1.1240 @ 25. C
PH 6.90 @ 21. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 48838.
TDS by Evapor. @ 110 C: 185100.

Refractive Index 1.36300 @ 25. C
Resistivity ohm/m 0.05700 @ 25. C
Calculated TDS : 166178.
TDS at Ignition : 163700.

Sample appearance:

THE SAMPLE CONSISTED OF MURKY SALT WATER.

Remarks:

FE TRACE. E78-3618-1 - TOP RESIS OF THE FILTRATE: .125, MUD. -2 - 1000 FT. FROM THE TOP RESIS: .057, MURKY WATER, H2S PRES. -3 - 150 FT. FROM THE TOP RESIS: .061, SAME AS -2. 4 - 57 FT. FROM TOP RESIS: .097, WATERY MUD. TRACE OF H2S. ALL RESIS OHM/M @ 25 C.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80827 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): 44629

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E78-3659-3

Well identifier	Well name	KB elev.	Gr. elev
0515043401000	ANDEX ET AL HIGHVALE 1-34-51-4	802.20	798.10

Interval Sampled from: 1727.00 to: 1748.00 meters KB

Formation Sampled: WABAMUN

Sample produced by: DST # 3 Sampling point:BOTTOM
DST Recovery
96.00 M GAS-CUT MUD

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na+K	2422.		
Ca	9.	0.420	0.4
Mg	4.	0.308	0.3

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	2439.	64.340	68.8
HCO3	1298.	19.895	21.3
SO4	665.	12.949	13.8
CO3	67.	2.088	2.2

Specific gravity 1.0070 @ 25. C
PH 9.00 @ 22. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 2422.
TDS by Evapor. @ 110 C: 7940.

Refractive Index 1.33420 @ 25. C
Resistivity ohm/m 0.96200 @ 25. C
Calculated TDS : 6245.
TDS at Ignition : 5540.

Sample appearance:

THE ANALYSIS DETERMINED ON WATER FILTERED FROM MUD.

Remarks:

FE NIL. E78-3659-1 - TOP RESIS OF THE FILTRATE; 1.05, MUD SAMPLE. -2 - MIDDLE RESIS OF THE FILTRATE: .962, MUD SAMPLE. -4 - DHS A LYNES UNITED DHS REC'D AT ATM. PRESSURE. CONTAINED IN THE CHAMBER WAS A SMALL QUANTITY OF MUD ONLY. THERE WAS INSUFFICIENT SAMPLE FOR ANY ANALYSIS. ALL RESIS OHM/M @ 25 C.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80801 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): 44599

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E81-7087-3

Well identifier	Well name	KB elev.	Gr. elev
0515041816000	ANDEX ET AL HIGHVALE 16-18-51-4	799.00	794.90

Interval Sampled from: 1651.00 to: 1656.00 meters KB

Formation Sampled: BANFF

Sample produced by: DST # 2 Sampling point:BOTTOM
DST Recovery
36.00 M OIL-CUT MUD
69.00 M OIL-CUT SALT WATER
Date: Sampled: 1981/09/20 Received: 1981/09/23 Analyzed: 1981/10/13

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	35876.	44.312	1560.5
K	851.	0.618	21.8
Ca	2755.	3.904	137.5
Mg	496.	1.159	40.8

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	62000.	49.659	1748.8
HCO3	276.	0.128	4.5
SO4	372.	0.220	7.7

Specific gravity 1.0700 @ 25. C
PH 7.10 @ 21. C
Refractive Index 1.34980 @ 25. C
Resistivity ohm/m 0.07700 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 36391.
Calculated TDS : 102150.
TDS by Evapor. @ 110 C: 106400.
TDS at Ignition : 96320.

Sample appearance:

THE SAMPLE CONSISTED OF MUDDY SALT WATER WITH A SCUM OF OIL PRES.

Remarks:

FE PRES. E81-7087-1: TOP RESIS: .179, MUD. TRACE OF OIL. -2: MIDDLE RESIS: .090, SL. MUDDY WATER, OIL SCUM. H2S PRES. BOTH RESIS OHM/M @ 25 C.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80811 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 44606

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E82-736-1

Well identifier	Well name	KB elev.	Gr. elev
0515042114000	ANDEX COLGAS HIGHVALE 14-21-51-4	814.60	810.50

Interval Sampled from: 1620.00 to: 1622.00 meters KB

Formation Sampled: BF 6440

Sample produced by:Swabbing Sampling point:WELLHEAD
Date: Sampled: 1982/05/21 Received: 1982/05/25 Analyzed: 1982/05/26

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	29920.	44.682	1301.4
K	534.	0.469	13.7
Ca	2042.	3.498	101.9
Mg	578.	1.633	47.6

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	50300.	48.710	1418.8
HCO3	1449.	0.815	23.7
SO4	270.	0.193	5.6

Specific gravity 1.0580 @ 25. C
PH 7.10 @ 20. C
Refractive Index 1.34730 @ 25. C
Resistivity ohm/m 0.08800 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 29860.
Calculated TDS : 83762.
TDS by Evapor. @ 110 C: 86300.
TDS at Ignition : 80760.

Sample appearance:

THE ANALYSIS IS CHARACTERISTIC OF A FORMATION WATER.

Remarks:

FE MUCH.

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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      80811    Chemistry number:    2
AGSWDB Hard copy number    (HRDCPNO):     44607

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. E82-736-2

Well identifier  Well name                              KB elev. Gr. elev
0515042114000    ANDEX COLGAS HIGHVALE 14-21-51-4         814.60    810.50

Interval Sampled from:    1620.00  to:    1622.00 meters KB

Formation Sampled: BF 6440

Sample produced by:Swabbing                   Sampling point:WELLHEAD
 Date:    Sampled:  1982/05/21  Received: 1982/05/25  Analyzed: 1982/05/26

               CATIONS                                     ANIONS
|------------------------------------|   |------------------------------------|
| ION  |       mg/l    | %MEQ  | MEQ/L |   | ION  |       mg/l    | %MEQ  | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na    |        30280.| 44.747| 1317.1|   |Cl    |        50700.| 48.585| 1430.1|
|K     |          573.| 0.498|   14.7|   |HCO3  |         1486.| 0.827|   24.4|
|Ca    |         2146.| 3.638|  107.1|   |SO4   |          280.| 0.198|    5.8|
|Mg    |          539.| 1.507|   44.4|   |      |              |      |       |
|      |              |      |       |   |      |              |      |       |
|------------------------------------|   |------------------------------------|

Specific gravity      1.0590 @  25. C   Refractive Index     1.34740 @  25. C
PH                      7.20 @  20. C   Resistivity ohm/m    0.08800 @  25. C
Hydrogen Sulfide Description:
Organics Description            :
Calculated sodium:        30092.        Calculated TDS :          84488.
TDS by Evapor. @ 110 C:        87440.   TDS at Ignition :              81860.

Sample appearance:

THE ANALYSIS IS CHARACTERISTIC OF A FORMATION WATER.

Remarks:

FE PRES.
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      80811    Chemistry number:    3
AGSWDB Hard copy number    (HRDCPNO):     44608

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. B82-6697

Well identifier  Well name                              KB elev. Gr. elev
0515042114000    ANDEX COLGAS HIGHVALE 14-21-51-4         814.60    810.50

Interval Sampled from:    1628.00  to:    1638.00 meters KB

Formation Sampled: ELRSL 3360

Sample produced by:                           Sampling point:TOP OF TOOL
 Date:    Sampled:  1982/11/09  Received: 1982/11/18  Analyzed: 1982/12/03

               CATIONS                                     ANIONS
|------------------------------------|   |------------------------------------|
| ION  |       mg/l    | %MEQ  | MEQ/L |   | ION  |       mg/l    | %MEQ  | MEQ/L |
|------------------------------------|   |------------------------------------|
|Na    |        13500.| 46.131|  587.2|   |Cl    |        22000.| 48.748|  620.5|
|K     |          145.| 0.291|    3.7|   |HCO3  |          451.| 0.581|    7.4|
|Ca    |          625.| 2.450|   31.2|   |SO4   |          436.| 0.713|    9.1|
|Mg    |          168.| 1.086|   13.8|   |      |              |      |       |
|      |              |      |       |   |      |              |      |       |
|------------------------------------|   |------------------------------------|

Specific gravity      1.0240 @  25. C   Refractive Index     1.33930 @  25. C
PH                      7.80 @  21. C   Resistivity ohm/m    0.18200 @  25. C
Hydrogen Sulfide Description:
Organics Description            :
Calculated sodium:        13611.        Calculated TDS :          37062.
TDS by Evapor. @ 110 C:        38000.   TDS at Ignition :              34300.

Sample appearance:

ANALYSIS DETERMINED ON SALT WATER REC'D FROM OIL CUT MUD.

Remarks:

FE TRACE. E82-6697-1: TOP RESIS: 1.12, MUD. -2: MIDDLE RESIS: .229, WATER REC'
D FROM OIL CUT MUD. -4: DHS STRAT HUGHES DHS WAS REC'D EMPTY. BOTH RESIS OHM/M
 @ 25 C.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80782 Chemistry number: 3
AGSWDB Hard copy number (HRDCPNO): 44588

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E82-5374-2

Well identifier	Well name	KB elev.	Gr. elev
0515041513000	ANDEX ET AL HIGHVALE 13-15-51-4	826.30	822.20

Interval Sampled from: 1630.00 to: 1639.00 meters KB

Formation Sampled: RUN 6100

Sample produced by: DST # 1 Sampling point:DHS
DST Recovery
500.00 M CLEAN OIL
Date: Sampled: 1982/10/07 Received: 1982/10/12 Analyzed: 1982/10/29

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	25040.	45.799	1089.2
K	326.	0.351	8.3
Ca	1602.	3.361	79.9
Mg	330.	1.142	27.2

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	41000.	48.628	1156.5
HCO3	960.	0.662	15.7
SO4	66.	0.058	1.4

Specific gravity 1.0480 @ 25. C
PH 6.90 @ 23. C
Refractive Index 1.34430 @ 25. C
Resistivity ohm/m 0.10600 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 24520.
Calculated TDS : 67990.
TDS by Evapor. @ 110 C: 70280.
TDS at Ignition : 63560.

Sample appearance:

STRATR HUGHES TESTERS DHS REC'D UNDER ATM. PRESSURE AND CONTAINED 3.0 L OF MUDDY WATER CUT OIL.

Remarks:

FE PRES.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80795 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 44594

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E84-9739

Well identifier	Well name	KB elev.	Gr. elev
0515041616000	ANDEX ET AL HIGHVALE 16-16-51-4	798.90	794.80

Interval Sampled from: 1605.00 to: 1610.00 meters KB

Formation Sampled: ELRSL. 3360

Sample produced by: Sampling point:
Date: Sampled: 1984/10/19 Received: 1984/10/27 Analyzed: 1984/11/05

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	4880.	44.808	212.3
K	99.	0.534	2.5
Ca	171.	1.801	8.5
Mg	67.	1.164	5.5

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	7870.	46.859	222.0
HCO3	1303.	4.508	21.4
SO4	74.	0.325	1.5

Specific gravity 1.0090 @ 25. C
PH 8.10 @ 25. C
Refractive Index 1.33540 @ 25. C
Resistivity ohm/m 0.44300 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 5307.
Calculated TDS : 14130.
TDS by Evapor. @ 110 C: 16460.
TDS at Ignition : 13260.

Sample appearance:

THE WATER HAD A TRACE OF HYDRO. SCUM PRES.

Remarks:

FE PRES.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80799 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 44596

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E82-10976-5

Well identifier	Well name	KB elev.	Gr. elev
0515041808000	ANDEX ET AL HIGHVALE 8-18-51-4	783.60	779.50

Interval Sampled from: 1592.00 to: 1602.00 meters KB

Formation Sampled: OST

Sample produced by: DST # 1 Sampling point:DHS
DST Recovery
30.00 M OIL-CUT MUD
315.00 M OIL-CUT MUD
Date: Sampled: 1982/01/15 Received: 1982/01/18 Analyzed: 1982/01/25

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	27400.	46.293	1191.8
K	374.	0.372	9.6
Ca	1093.	2.118	54.5
Mg	379.	1.211	31.2

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	45200.	49.521	1274.9
HCO3	576.	0.367	9.4
SO4	146.	0.118	3.0

Specific gravity 1.0490 @ 25. C
PH 6.40 @ 23. C
Refractive Index 1.34590 @ 25. C
Resistivity ohm/m 0.10400 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 27629.
TDS by Evapor. @ 110 C: 77060.
Calculated TDS : 74730.
TDS at Ignition : 70500.

Sample appearance:

A QUINN TESTERS DHS #1506 REC'D AT 3500 KPA. IT CONTAINED GAS AND 1.4 L OF OIL CUT MUD.

Remarks:

FE PRES. E82-10976-1: TOP OF TOOL SAMLL QUANTITY OF OILY MUD. INSUFFICIENT FOR ANALYSIS. -2: 190 M ABO TOOL RESIS: .103, SL. OIL CUT WATERY MUD. -3: 322 M ABO TOOL RESIS: .111, SL. OIL CUT MUDDY WATER. ALL RESIS OHM/M @ 25 C.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80801 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 44598

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E81-7483

Well identifier	Well name	KB elev.	Gr. elev
0515041816000	ANDEX ET AL HIGHVALE 16-18-51-4	799.00	794.90

Interval Sampled from: 1651.00 to: 1656.00 meters KB

Formation Sampled: BANFF

Sample produced by: DST # 2 Sampling point:BHS
DST Recovery
36.00 M OIL-CUT MUD
69.00 M OIL-CUT SALT WATER
Date: Sampled: 1981/09/20 Received: 1981/10/01 Analyzed: 1981/10/19

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	35329.	43.559	1536.7
K	749.	0.543	19.2
Ca	2843.	4.021	141.9
Mg	802.	1.871	66.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	62000.	49.570	1748.8
HCO3	490.	0.228	8.0
SO4	352.	0.208	7.3

Specific gravity 1.0700 @ 25. C
PH 7.80 @ 23. C
Refractive Index 1.34980 @ 25. C
Resistivity ohm/m 0.08900 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 35783.
TDS by Evapor. @ 110 C: 104400.
Calculated TDS : 102020.
TDS at Ignition : 96240.

Sample appearance:

A LYNES UNITED DHS REC'D UNDER ATM. PRESSURE AND CONTAINED 2.3 L OF MUDDY SALT WATER ONLY.

Remarks:

FE TRACE.

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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      80768    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     44577

CHEMICAL & GEOLOGICAL LAB LTD                    Lab. Sample ID. E82-13903

Well identifier  Well name                                 KB elev. Gr. elev
0515041106000    ANDEX ET AL HIGHVALE 6-11-51-4               760.70    756.60

Interval Sampled from:   1574.50  to:   1575.50 meters KB

Formation Sampled: BF 6440.

Sample produced by:                              Sampling point:WELLHEAD
                 CATIONS                                     ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION  |       mg/l     | %MEQ  | MEQ/L |  |  ION  |       mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na     |         26710.| 45.754| 1161.8|  |Cl     |         44000.| 48.876| 1241.1|
|K      |           651.|  0.656|   16.6|  |HCO3   |           974.|  0.629|   16.0|
|Ca     |          1574.|  3.093|   78.5|  |SO4    |            21.|  0.017|    0.4|
|Mg     |           301.|  0.975|   24.8|  |       |               |       |       |
|       |               |       |       |  |       |               |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity      1.0500 @  25. C    Refractive Index      1.34500 @  25. C
PH                      6.80 @  24. C    Resistivity ohm/m     0.11000 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:          26537.       Calculated TDS :             72911.
TDS by Evapor. @ 110 C:          76100.  TDS at Ignition :               71540.

Remarks:

FE NIL.
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):      80775    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):     44584

CHEMICAL & GEOLOGICAL LAB LTD                    Lab. Sample ID. D78-10154-1

Well identifier  Well name                                 KB elev. Gr. elev
0515041404000    SIEBENS ET AL HIGHVALE 4-14-51-4             777.50    773.60

Interval Sampled from:   1944.62  to:   1965.35 meters KB

Formation Sampled: WINTERBURN

Sample produced by: DST #    4                   Sampling point:
  DST Recovery
        27.40 M   SALT WATER-CUT MUD
     1396.00 M   SULPHUROUS SALT WATER
 Date:   Sampled:  1978/06/27  Received: 1978/07/12  Analyzed: 1978/07/31

                 CATIONS                                     ANIONS
|-------------------------------------|  |-------------------------------------|
|  ION  |       mg/l     | %MEQ  | MEQ/L |  |  ION  |       mg/l     | %MEQ  | MEQ/L |
|-------------------------------------|  |-------------------------------------|
|Na     |         46681.| 33.996| 2030.5|  |Cl     |        105400..| 49.775| 2973.0|
|K      |          2775.|  1.188|   71.0|  |HCO3   |           183.|  0.050|    3.0|
|Ca     |         13700.| 11.446|  683.6|  |SO4    |           516.|  0.180|   10.7|
|Mg     |          2442.|  3.364|  200.9|  |       |               |       |       |
|       |               |       |       |  |       |               |       |       |
|-------------------------------------|  |-------------------------------------|

Specific gravity      1.1280 @  16. C    Refractive Index      1.36340 @  25. C
PH                      6.50 @  27. C    Resistivity ohm/m     0.05500 @  25. C
Hydrogen Sulfide Description:
Organics Description          :
Calculated sodium:          48335.       Calculated TDS :            170483.
TDS by Evapor. @ 110 C:         193100.  TDS at Ignition :              172000.

Sample appearance:

BLACK WATER. MUCH H2S PRES.

Remarks:

FE PRES.
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     80782    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):    44586

CHEMICAL & GEOLOGICAL LAB LTD                  Lab. Sample ID. E84-9738

Well identifier  Well name                               KB elev. Gr. elev
0515041513000    ANDEX ET AL HIGHVALE 13-15-51-4            826.30    822.20

Interval Sampled from:    1634.20   to:    1637.00 meters KB

Formation Sampled: ELRSL. 3360

Sample produced by:                             Sampling point:
 Date:   Sampled:  1984/10/19  Received: 1984/10/25  Analyzed: 1984/11/15

              CATIONS                                  ANIONS
|--------------------------------------|  |--------------------------------------|
|  ION  |      mg/l      | %MEQ  | MEQ/L |  |  ION  |      mg/l      | %MEQ  | MEQ/L |
|--------------------------------------|  |--------------------------------------|
|Na     |         28450.| 45.274| 1237.5|  |Cl     |         48800.| 50.357| 1376.5|
|K      |           361.|  0.338|    9.2|  |HCO3   |          1413.|  0.847|   23.2|
|Ca     |          1193.|  2.178|   59.5|  |SO4    |            72.|  0.055|    1.5|
|Mg     |           316.|  0.951|   26.0|  |       |               |       |       |
|       |               |       |       |  |       |               |       |       |
|--------------------------------------|  |--------------------------------------|

Specific gravity      1.0530 @  25. C   Refractive Index      1.34600 @  25. C
PH                      8.10 @  25. C   Resistivity ohm/m     0.09400 @  25. C
Hydrogen Sulfide Description:
Organics Description           :
Calculated sodium:        30248.        Calculated TDS :          81324.
TDS by Evapor. @ 110 C:       100900.   TDS at Ignition :              73420.

Remarks:

FE NIL.
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     80782    Chemistry number:    2
AGSWDB Hard copy number    (HRDCPNO):    44587

CHEMICAL & GEOLOGICAL LAB LTD                  Lab. Sample ID. E84-10664

Well identifier  Well name                               KB elev. Gr. elev
0515041513000    ANDEX ET AL HIGHVALE 13-15-51-4            826.30    822.20

Interval Sampled from:    1632.00   to:    1633.00 meters KB
Interval Sampled from:    1634.20   to:    1637.00 meters KB

Formation Sampled: ELRSL. 3360

Sample produced by:                             Sampling point:
              CATIONS                                  ANIONS
|--------------------------------------|  |--------------------------------------|
|  ION  |      mg/l      | %MEQ  | MEQ/L |  |  ION  |      mg/l      | %MEQ  | MEQ/L |
|--------------------------------------|  |--------------------------------------|
|Na     |         26380.| 45.127| 1147.5|  |Cl     |         44840.| 49.741| 1264.8|
|K      |           331.|  0.333|    8.5|  |HCO3   |          1293.|  0.833|   21.2|
|Ca     |          1558.|  3.058|   77.7|  |SO4    |            62.|  0.051|    1.3|
|Mg     |           265.|  0.858|   21.8|  |       |               |       |       |
|       |               |       |       |  |       |               |       |       |
|--------------------------------------|  |--------------------------------------|


         Other Determinations
|----------------------------------------|
|Parameter                    |   mg/l    |
|----------------------------------------|
|boron                        |        7. |
|strontium                    |      208. |
|----------------------------------------|

Specific gravity      1.0500 @  25. C   Refractive Index      1.34470 @  25. C
PH                      7.70 @  22. C   Resistivity ohm/m     0.10100 @  25. C
Hydrogen Sulfide Description:
Organics Description           :
Calculated sodium:        27308.        Calculated TDS :          74668.
TDS by Evapor. @ 110 C:        85470.   TDS at Ignition :              71090.

Remarks:

FE PRES.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80748 Chemistry number: 2
AGSWDB Hard copy number (HRDCPNO): 44553

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. D78-9259-3

Well identifier	Well name	KB elev.	Gr. elev
0515040805000	ANDEX ET AL HIGHVALE 5-8-51-4	757.30	753.20

Interval Sampled from: 1569.72 to: 1584.96 meters KB

Formation Sampled: BANFF

Sample produced by: DST # 2 Sampling point:BOTTOM
DST Recovery
137.20 M GAS-CUT MUD
45.70 M OIL-CUT MUD
Date: Sampled: 1978/06/17 Received: 1978/06/20 Analyzed: 1978/06/20

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na+K	4057.		
Ca	205.	4.890	10.2
Mg	74.	2.911	6.1

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	4700.	63.374	132.6
HCO3	930.	7.286	15.2
SO4	2164.	21.539	45.1

Specific gravity 1.0080 @ 16. C Refractive Index 1.33520 @ 25. C
PH 8.20 @ 25. C Resistivity ohm/m 0.52800 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 4059. Calculated TDS : 11659.
TDS by Evapor. @ 110 C: 11950. TDS at Ignition : 11250.

Sample appearance:

THE SAMPLE CONSISTED OF OIL FLECKED WATERY MUD.

Remarks:

FE PRES. D78-9259-1 TOP RESIS: .585, MUD. -2: MIDDLE RESIS: .532, MUD. BOTH RESIS OHM/M @ 25 C.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 80758 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 44568

CORE LABORATORIES CANADA LT. Lab. Sample ID. 7021-81-107

Well identifier	Well name	KB elev.	Gr. elev
0515040916000	ANDEX ET AL HIGHVALE 16-9-51-4	782.10	778.00

Interval Sampled from: 1583.00 to: 1587.00 meters KB

Formation Sampled: GLC.

Sample produced by: Sampling point:BRINE H2O SAMPLE
Date: Sampled: 1981/02/08 Received: 1981/02/09 Analyzed: 1981/02/11

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	90750.	49.432	3947.4
K	241.	0.077	6.2
Ca	690.	0.431	34.4
Mg	70.	0.072	5.8

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	140798.	49.732	3971.4
HCO3	741.	0.152	12.1
SO4	395.	0.103	8.2

Specific gravity 1.1478 @ 15. C Refractive Index 1.36680 @ 22. C
PH 7.70 @ 0. C Resistivity ohm/m 0.04800 @ 25. C
Hydrogen Sulfide Description:
Calculated sodium: 90853. Calculated TDS : 233170.

Remarks:

FE TRACE. NACL EQUIV 232981. CHLOROFORM EXTRACTION RESIDUE = <10 MG/L.

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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     80762    Chemistry number:    2
AGSWDB Hard copy number    (HRDCPNO):    44571

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. D77-1666-3

Well identifier  Well name                             KB elev. Gr. elev
0515041006000    ANDEX ET AL HIGHVALE 6-10-51-4           772.40    768.40

Interval Sampled from:    1573.38   to:    1579.47 meters KB

Formation Sampled: BF

Sample produced by: DST #     3                Sampling point:BOTTOM
  DST Recovery
        91.40 M   CLEAN OIL
        35.40 M   OIL-CUT MUD
 Date:   Sampled:  1977/10/24  Received: 1977/11/01  Analyzed: 1977/12/09

                CATIONS                                 ANIONS
|------------------------------------|  |-------------------------------------|
|  ION  |      mg/l      | %MEQ  | MEQ/L |  |  ION  |      mg/l      | %MEQ  | MEQ/L |
|------------------------------------|  |-------------------------------------|
|Na     |         7197.| 47.768|  313.1|  |Cl     |        10025.| 43.147|  282.8|
|Ca     |          164.|  1.249|    8.2|  |HCO3   |         2080.|  5.202|   34.1|
|Mg     |           78.|  0.979|    6.4|  |SO4    |          521.|  1.655|   10.8|
|       |              |       |       |  |       |              |       |       |
|------------------------------------|  |-------------------------------------|

Specific gravity       1.0160 @  16. C   Refractive Index      1.33640 @  25. C
PH                       7.30 @  21. C   Resistivity ohm/m     0.32300 @  25. C
Hydrogen Sulfide Description:
Organics Description           :
Calculated sodium:          7199.         Calculated TDS :           19009.
TDS by Evapor. @ 110 C:         20360.    TDS at Ignition :              17740.

Sample appearance:

THE SAMPLE CONSISTED OF WATER WITH A LAYER OF OIL.

Remarks:

FE PRES. D77-1666-2 MIDDLE RESIS; .431 OHM/M @ 25 C. SL. OIL CUT MUD.
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                   | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     80762    Chemistry number:    3
AGSWDB Hard copy number    (HRDCPNO):    44572

CHEMICAL & GEOLOGICAL LAB LTD                Lab. Sample ID. D77-1667-3

Well identifier  Well name                             KB elev. Gr. elev
0515041006000    ANDEX ET AL HIGHVALE 6-10-51-4           772.40    768.40

Interval Sampled from:    1580.08   to:    1587.40 meters KB

Formation Sampled: BF

Sample produced by: DST #     5                Sampling point:234 FT.
  DST Recovery
       247.20 M   CLEAN OIL
        26.80 M   MUD
        44.50 M   WATER
 Date:   Sampled:  1977/10/24  Received: 1977/11/01  Analyzed: 1977/11/29

                CATIONS                                 ANIONS
|------------------------------------|  |-------------------------------------|
|  ION  |      mg/l      | %MEQ  | MEQ/L |  |  ION  |      mg/l      | %MEQ  | MEQ/L |
|------------------------------------|  |-------------------------------------|
|Na     |        26751.| 45.807| 1163.6|  |Cl     |        44524.| 49.439| 1255.9|
|Ca     |         1228.|  2.412|   61.3|  |HCO3   |          657.|  0.424|   10.8|
|Mg     |          548.|  1.775|   45.1|  |SO4    |          175.|  0.143|    3.6|
|       |              |       |       |  |       |              |       |       |
|------------------------------------|  |-------------------------------------|

Specific gravity       1.0530 @  16. C   Refractive Index      1.34530 @  25. C
PH                       7.20 @  21. C   Resistivity ohm/m     0.11300 @  25. C
Hydrogen Sulfide Description:
Organics Description           :
Calculated sodium:         26760.         Calculated TDS :           73558.
TDS by Evapor. @ 110 C:         81160.    TDS at Ignition :              70200.

Sample appearance:

THE SAMPLE CONSISTED OF CLEAR WATER.

Remarks:

FE PRES. D77-1667-4 BOTTOM RESIS: .439 OHM/M @ 25 C. MUD SAMPLE.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 138182 Chemistry number: 5
AGSWDB Hard copy number (HRDCPNO): -1856310

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E86-1963-1

Well identifier	Well name	KB elev.	Gr. elev
0495053514000	ENRON ET AL PEMBINA 14-35-49-5	763.10	758.30

Interval Sampled from: 1683.00 to: 1692.00 meters KB

Formation Sampled: ELRS

Sample produced by: DST # 3 Sampling point:MIDDLE
DST Recovery
96.00 M GAS-CUT MUD
194.00 M GAS-CUT SALT WATER
Date: Sampled: 1986/12/05 Received: 1986/12/08 Analyzed: 1986/12/15

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	23650.	45.425	1028.7
K	299.	0.338	7.6
Ca	1169.	2.576	58.3
Mg	365.	1.326	30.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	39500.	49.197	1114.2
HCO3	1359.	0.983	22.3
SO4	169.	0.155	3.5

Specific gravity 1.0410 @ 25. C
PH 6.90 @ 21. C
Refractive Index 1.34330 @ 25. C
Resistivity ohm/m 0.11300 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 24178.
Calculated TDS : 66049.
TDS by Evapor. @ 110 C: 64040.
TDS at Ignition : 61380.

Sample appearance:

ORGANICS: TRACE. SAMPLE CONSISTED OF SALT WATER WITH AN IRON SUSPENSION.

Remarks:

Fe TRACE

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 138478 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): 39772

CHEMICAL & GEOLOGICAL LAB LTD Lab. Sample ID. E85-550-5

Well identifier	Well name	KB elev.	Gr. elev
0505053606000	ANDEX ET AL HIGHVALE 6-36-50-5	755.30	750.50

Interval Sampled from: 1613.00 to: 1630.00 meters KB

Formation Sampled: BANFF

Sample produced by: DST # 1 Sampling point:DHS
DST Recovery
202.00 M CLEAN OIL
Date: Sampled: 1985/12/12 Received: 1985/12/17 Analyzed: 1985/12/23

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	35530.	44.814	1545.5
K	790.	0.586	20.2
Ca	2458.	3.557	122.7
Mg	855.	2.040	70.4

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	59100.	48.337	1667.0
HCO3	1005.	0.478	16.5
SO4	313.	0.189	6.5

Specific gravity 1.0590 @ 25. C
PH 7.40 @ 23. C
Refractive Index 1.34860 @ 25. C
Resistivity ohm/m 0.08100 @ 25. C
Hydrogen Sulfide Description:
Organics Description :
Calculated sodium: 34419.
Calculated TDS : 97639.
TDS by Evapor. @ 110 C: 106000.
TDS at Ignition : 92500.

Sample appearance:

LYNES DHS REC'D @ATM PRESSURE, 2.3L OF SALT WATER CUT OIL (59% OIL).

Remarks:

FE TRACE. E85-550-2 TOP RES: .139 OHM/M @25C OIL CUT MUDDY WATER (30% OIL). -3 BOTTOM OF LAST COLLAR RES: .091 OHM/M @25C SLIGHTLY OIL STAINED MUDDY WATER

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                    | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     151481    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):  -1994409

CHEMEX LABS (ALBERTA) LTD.                       Lab. Sample ID. 88-0201-8061

Well identifier  Well name                                KB elev. Gr. elev
0495031411000    362107 PEMBINA 11-14-49-3                  770.10    765.90

Interval Sampled from:    1551.00  to:    1556.00 meters KB

Formation Sampled: GLC SS

Sample produced by:                              Sampling point:RIG TANK
 Date:    Sampled:  1988/03/22  Received: 1988/03/24  Analyzed: 1988/03/29

              CATIONS                                     ANIONS
|----------------------------------------|   |----------------------------------------|
|  ION   |       mg/l     | %MEQ  | MEQ/L |   |  ION   |       mg/l     | %MEQ  | MEQ/L |
|----------------------------------------|   |----------------------------------------|
|Na      |         29200.| 45.250| 1270.1|   |Cl      |         50000.| 50.244| 1410.3|
|K       |           297.|  0.271|    7.6|   |HCO3    |           549.|  0.321|    9.0|
|Ca      |          1680.|  2.987|   83.8|   |SO4     |            14.|  0.010|    0.3|
|Mg      |           301.|  0.882|   24.8|   |        |               |       |       |
|Fe      |            28.|  0.036|    1.0|   |        |               |       |       |
|----------------------------------------|   |----------------------------------------|

Specific gravity       1.0630 @    0. C   Refractive Index       1.34840 @    0. C
PH                       6.80 @   25. C   Resistivity ohm/m      0.12400 @   25. C
Hydrogen Sulfide Description:
Calculated sodium:          30142.        Calculated TDS :             82407.

Sample appearance:

CO3 < 0.5. IRON ANALYZED ON FILTERED SAMPLE.
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                    | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):     151481    Chemistry number:    2
AGSWDB Hard copy number    (HRDCPNO):  -2003302

CHEMEX LABS (ALBERTA) LTD.                       Lab. Sample ID. 88-0201-8048

Well identifier  Well name                                KB elev. Gr. elev
0495031411000    362107 PEMBINA 11-14-49-3                  770.10    765.90

Interval Sampled from:    1551.00  to:    1556.00 meters KB

Formation Sampled: GLC SS

Sample produced by:                              Sampling point:TEST SEPARATOR
 Date:    Sampled:  1988/03/13  Received: 1988/03/15  Analyzed: 1988/03/18

              CATIONS                                     ANIONS
|----------------------------------------|   |----------------------------------------|
|  ION   |       mg/l     | %MEQ  | MEQ/L |   |  ION   |       mg/l     | %MEQ  | MEQ/L |
|----------------------------------------|   |----------------------------------------|
|Na      |         29500.| 45.583| 1283.2|   |Cl      |         50000.| 50.100| 1410.3|
|K       |           305.|  0.277|    7.8|   |HCO3    |          2060.|  1.199|   33.8|
|Ca      |          1140.|  2.021|   56.9|   |SO4     |            75.|  0.055|    1.6|
|Mg      |           261.|  0.763|   21.5|   |        |               |       |       |
|Fe      |             1.|  0.002|    0.0|   |        |               |       |       |
|----------------------------------------|   |----------------------------------------|

Specific gravity       1.0620 @    0. C   Refractive Index       1.34750 @    0. C
PH                       7.50 @   25. C   Resistivity ohm/m      0.10600 @   25. C
Hydrogen Sulfide Description:
Calculated sodium:          31436.        Calculated TDS :             83925.

Sample appearance:

CO3 <, 0.5. IRON ANALYZED ON FILTERED SAMPLE.
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    151483    Chemistry number:    1
AGSWDB Hard copy number    (HRDCPNO):  -1958101

AGAT ENGINEERING LTD                               Lab. Sample ID. WE8500

Well identifier  Well name                                  KB elev. Gr. elev
0495050302000    BUMPER ET AL PEMBINA 2-3-49-5                 772.60    767.80

Interval Sampled from:    1754.00  to:    1759.00 meters KB

Formation Sampled: NORD

Sample produced by:                                Sampling point:SWAB
 Date:   Sampled:  1987/11/27  Received: 1987/12/02  Analyzed: 1987/12/16

                CATIONS                                       ANIONS
|------------------------------------|     |------------------------------------|
|  ION  |     mg/l      | %MEQ  | MEQ/L |     |  ION  |     mg/l      | %MEQ  | MEQ/L |
|------------------------------------|     |------------------------------------|
|Na     |        11000.| 41.265|  478.5|     |Cl     |        20000.| 48.652|  564.1|
|K      |          382.|  0.843|    9.8|     |HCO3   |          705.|  0.996|   11.6|
|Ca     |         1420.|  6.111|   70.9|     |SO4    |          536.|  0.962|   11.2|
|Mg     |          156.|  1.107|   12.8|     |       |              |       |       |
|Fe     |           21.|  0.063|    0.7|     |       |              |       |       |
|------------------------------------|     |------------------------------------|

Specific gravity      1.0210 @   0. C
PH                      7.20 @  25. C   Resistivity ohm/m    0.26000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:         11568.       Calculated TDS :          34027.

Sample appearance:

SALINITY=3.53%.TRC+=LESS THAN 0.1.N.D.=NOT DETECTED.NIL=0.0.TRC*=LESS THAN 0.0
01.N.A.=NOT ANALYZED.
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                  | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    151483    Chemistry number:    2
AGSWDB Hard copy number    (HRDCPNO):  -1994410

AGAT ENGINEERING LTD                               Lab. Sample ID. WE8265D

Well identifier  Well name                                  KB elev. Gr. elev
0495050302000    BUMPER ET AL PEMBINA 2-3-49-5                 772.60    767.80

Interval Sampled from:    1754.00  to:    1762.00 meters KB

Formation Sampled: NORD

Sample produced by: DST #    2                     Sampling point:BHS
  DST Recovery
        80.00 M   GAS- AND OIL-CUT MUD
 Date:   Sampled:  1987/09/30  Received: 1987/10/06  Analyzed: 1987/10/21

                CATIONS                                       ANIONS
|------------------------------------|     |------------------------------------|
|  ION  |   . mg/l      | %MEQ  | MEQ/L |     |  ION  |     mg/l      | %MEQ  | MEQ/L |
|------------------------------------|     |------------------------------------|
|Na     |         3240.| 48.499|  140.9|     |Cl     |         4140.| 40.186|  116.8|
|K      |           38.|  0.330|    1.0|     |HCO3   |         1310.|  7.388|   21.5|
|Ca     |           67.|  1.152|    3.3|     |SO4    |          260.|  1.863|    5.4|
|Mg     |           20.|  0.558|    1.6|     |       |              |       |       |
|Fe     |            2.|  0.023|    0.1|     |       |              |       |       |
|------------------------------------|     |------------------------------------|

Specific gravity      1.0030 @   0. C
PH                      8.10 @  25. C   Resistivity ohm/m    0.71000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:          3189.       Calculated TDS :           8320.

Sample appearance:

BA,SR,BR,I,REF.INDEX=N.A.DST CHAMBER 2:OP,RECOVERY GAS +7000 MLS OIL/MUD.SALIN
ITY=0.75%.TRC+=LESS THAN 0.1.N.D.=NOT DETECTED.NIL=0.0.TRC*=LESS THAN 0.001.N.
A.=NOT ANALYZED.DST CHAMBER 2:O.P.758 KPA.
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    151483    Chemistry number:    3
AGSWDB Hard copy number    (HRDCPNO):  -1994411

AGAT ENGINEERING LTD                             Lab. Sample ID. WE8265C

Well identifier  Well name                                   KB elev. Gr. elev
0495050302000    BUMPER ET AL PEMBINA 2-3-49-5                  772.60    767.80

Interval Sampled from:    1754.00  to:    1762.00 meters KB

Formation Sampled: NORD

Sample produced by: DST #    2                 Sampling point:TOP OF TOOL
  DST Recovery
        80.00 M   GAS- AND OIL-CUT MUD
 Date:   Sampled:  1987/09/30  Received: 1987/10/06  Analyzed: 1987/10/21

                CATIONS                                     ANIONS
|-------------------------------------|    |-------------------------------------|
|  ION   |      mg/l      | %MEQ  | MEQ/L |    |  ION   |      mg/l      | %MEQ  | MEQ/L |
|-------------------------------------|    |-------------------------------------|
|Na      |           2430.| 50.344|  105.7|    |Cl      |           2790.| 37.482|   78.7|
|K       |             21.|  0.256|    0.5|    |HCO3    |            793.|  6.190|   13.0|
|Ca      |             30.|  0.723|    1.5|    |SO4     |            379.|  3.758|    7.9|
|Mg      |              7.|  0.286|    0.6|    |CO3     |             60.|  0.952|    2.0|
|Fe      | 0.50000        |  0.009|    0.0|    |        |                |       |       |
|-------------------------------------|    |-------------------------------------|

Specific gravity       1.0030 @    0. C
PH                       8.20 @   25. C   Resistivity ohm/m     0.94000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:           2287.         Calculated TDS :           5943.

Sample appearance:

BA, SR, BR, I & REF. INDEX=N.A.SALINITY=0.51%.TRC+=LESS THAN 0.1.N.D.=NOT DETE
CTED.NIL=0.0.TRC*=LESS THAN 0.001.N.A.=NOT ANALYZED.
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                 | AGSWDB WATER ANALYSIS REPORT |
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AGSWDB Well site identifier (SITID):    151483    Chemistry number:    5
AGSWDB Hard copy number    (HRDCPNO):  -1994501

AGAT ENGINEERING LTD                             Lab. Sample ID. WE8265B

Well identifier  Well name                                   KB elev. Gr. elev
0495050302000    BUMPER ET AL PEMBINA 2-3-49-5                  772.60    767.80

Interval Sampled from:    1754.00  to:    1762.00 meters KB

Formation Sampled: NORD

Sample produced by: DST #    2                 Sampling point:RIG FLOOR
  DST Recovery
        80.00 M   GAS- AND OIL-CUT MUD
 Date:   Sampled:  1987/09/30  Received: 1987/10/06  Analyzed: 1987/10/21

                CATIONS                                     ANIONS
|-------------------------------------|    |-------------------------------------|
|  ION   |      mg/l      | %MEQ  | MEQ/L |    |  ION   |      mg/l      | %MEQ  | MEQ/L |
|-------------------------------------|    |-------------------------------------|
|Na      |           1960.| 47.030|   85.3|    |Cl      |            860.| 13.381|   24.3|
|K       |             37.|  0.516|    0.9|    |HCO3    |           3130.| 28.297|   51.3|
|Ca      |             32.|  0.873|    1.6|    |SO4     |            565.|  6.489|   11.8|
|Mg      |             11.|  0.517|    0.9|    |CO3     |            156.|  2.868|    5.2|
|Fe      |              1.|  0.028|    0.1|    |        |                |       |       |
|-------------------------------------|    |-------------------------------------|

Specific gravity       1.0010 @    0. C
PH                       8.40 @   25. C   Resistivity ohm/m     1.28000 @  25. C
Hydrogen Sulfide Description:
Calculated sodium:           2069.         Calculated TDS :           5232.

Sample appearance:

BA, BR, SR, I & REF. INDEX=N.A.SALINITY=0.16%.TRC+=LESS THAN 0.1.N.D.=NOT DETE
CTED.NIL=0.0.TRC*=LESS THAN 0.001.N.A.=NOT ANALYZED.
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AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 151484 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): -2162409

AGAT ENGINEERING LTD
Lab. Sample ID. WE9197

Well identifier	Well name	KB elev.	Gr. elev
0495051314020	OMV ET AL PEMBINA 14-13-49-5	805.40	800.70

Interval Sampled from: 1737.00 to: 1740.50 meters KB

Formation Sampled: NORD

Sample produced by: DST # 1
Sampling point:TOP OF TOOL
DST Recovery
361.00 M GAS-CUT OIL
Date: Sampled: 1988/06/24 Received: 1988/06/29 Analyzed: 1988/07/06

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	22300.	41.314	970.0
K	690.	0.752	17.6
Ca	2790.	5.930	139.2
Mg	678.	2.376	55.8
Fe	0.40000	0.001	0.0

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	40600.	48.776	1145.2
HCO3	747.	0.521	12.2
SO4	372.	0.330	7.7

Specific gravity 1.0490 @ 0. C
PH 7.80 @ 25. C
Hydrogen Sulfide Description:
Calculated sodium: 22306.
Resistivity ohm/m 0.12000 @ 25. C
Calculated TDS : 67114.

Sample appearance:

BA,SR,BR,I, REFRACTIVE INDEX=N.A. DST 1. BHS=AL20.O.P.=O KPA. RECOVERY=NIL. SALINITY=6.99%. TRC+=LESS THAN 0.1. N.D.=NOT DETECTED. NIL=0.0. TRC*=LESS THAN 0.001. N.A.=NOT ANALYZED.

AGSWDB WATER ANALYSIS REPORT

AGSWDB Well site identifier (SITID): 151486 Chemistry number: 1
AGSWDB Hard copy number (HRDCPNO): -1981309

GEOTECH Analytical
Lab. Sample ID. 5996-W1

Well identifier	Well name	KB elev.	Gr. elev
0495052308020	CNW WESTGROWTH PEMBINA 8-23-49-5	809.70	805.50

Interval Sampled from: 1739.00 to: 1747.00 meters KB

Formation Sampled: NORD

Sample produced by: DST # 2
Sampling point:TOP OF TOOL
DST Recovery
50.00 M OIL-CUT MUD
426.00 M OIL-CUT SALT WATER

CATIONS

ION	mg/l	%MEQ	MEQ/L
Na	34400.	39.568	1496.3
K	1110.	0.751	28.4
Ca	4890.	6.453	244.0
Mg	1040.	2.263	85.6
Fe	34.	0.032	1.2

ANIONS

ION	mg/l	%MEQ	MEQ/L
Cl	67500.	50.347	1903.9
I	16.	0.003	0.1
HCO3	703.	0.305	11.5
SO4	506.	0.279	10.5

Other Determinations

Parameter	mg/l
barium	18.
strontium	345.

PH 6.70 @ 25. C
Calculated sodium: 36708.
Refractive Index 1.35500 @ 0. C
Resistivity ohm/m 0.07300 @ 25. C
Calculated TDS : 111005.

Sample appearance:

B=31.1. CATIONS/ANIONS: 0.97.

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                           ------------------------------
                          | AGSWDB WATER ANALYSIS REPORT |
                           ------------------------------

AGSWDB Well site identifier (SITID):     151486    Chemistry number:    3
AGSWDB Hard copy number   (HRDCPNO):   -1981311

GEOTECH Analytical                             Lab. Sample ID. 5936-W2

Well identifier  Well name                                KB elev. Gr. elev
0495052308020    CNW WESTGROWTH PEMBINA 8-23-49-5            809.70    805.50

Interval Sampled from:    1712.00  to:    1718.00 meters KB

Formation Sampled: OST

Sample produced by: DST #    5                 Sampling point:MIDDLE
  DST Recovery
        19.00 M    MUD
       267.00 M    SALT WATER
                 CATIONS                                     ANIONS
|-----------------------------------|  |-------------------------------------|
| ION  |       mg/l    | %MEQ  | MEQ/L |  | ION  |       mg/l    | %MEQ  | MEQ/L |
|-----------------------------------|  |-------------------------------------|
|Na      |        37400.| 39.996| 1626.8|  |Cl      |        72800.| 50.484| 2053.4|
|K       |          462.|  0.290|   11.8|  |I       |           13.|  0.002|    0.1|
|Ca      |         5290.|  6.490|  264.0|  |HCO3    |          482.|  0.194|    7.9|
|Mg      |         1210.|  2.448|   99.6|  |SO4     |          102.|  0.052|    2.1|
|Fe      |           49.|  0.043|    1.8|  |        |              |       |       |
|-----------------------------------|  |-------------------------------------|


         Other Determinations
|---------------------------------------|
|Parameter                   |    mg/l    |
|---------------------------------------|
|barium                      |         40.|
|boron                       |         29.|
|strontium                   |        590.|
|---------------------------------------|

                                         Refractive Index     1.35500 @    0. C
PH                          6.80 @  25. C   Resistivity ohm/m    0.07000 @   25. C
Calculated sodium:           39087.         Calculated TDS :       118739.

Sample appearance:

B=29.2. CATIONS/ANIONS: 0.90.
                         ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

APPENDIX 11.3.3

X-Ray Diffractograms of Aquifer Mineralogy

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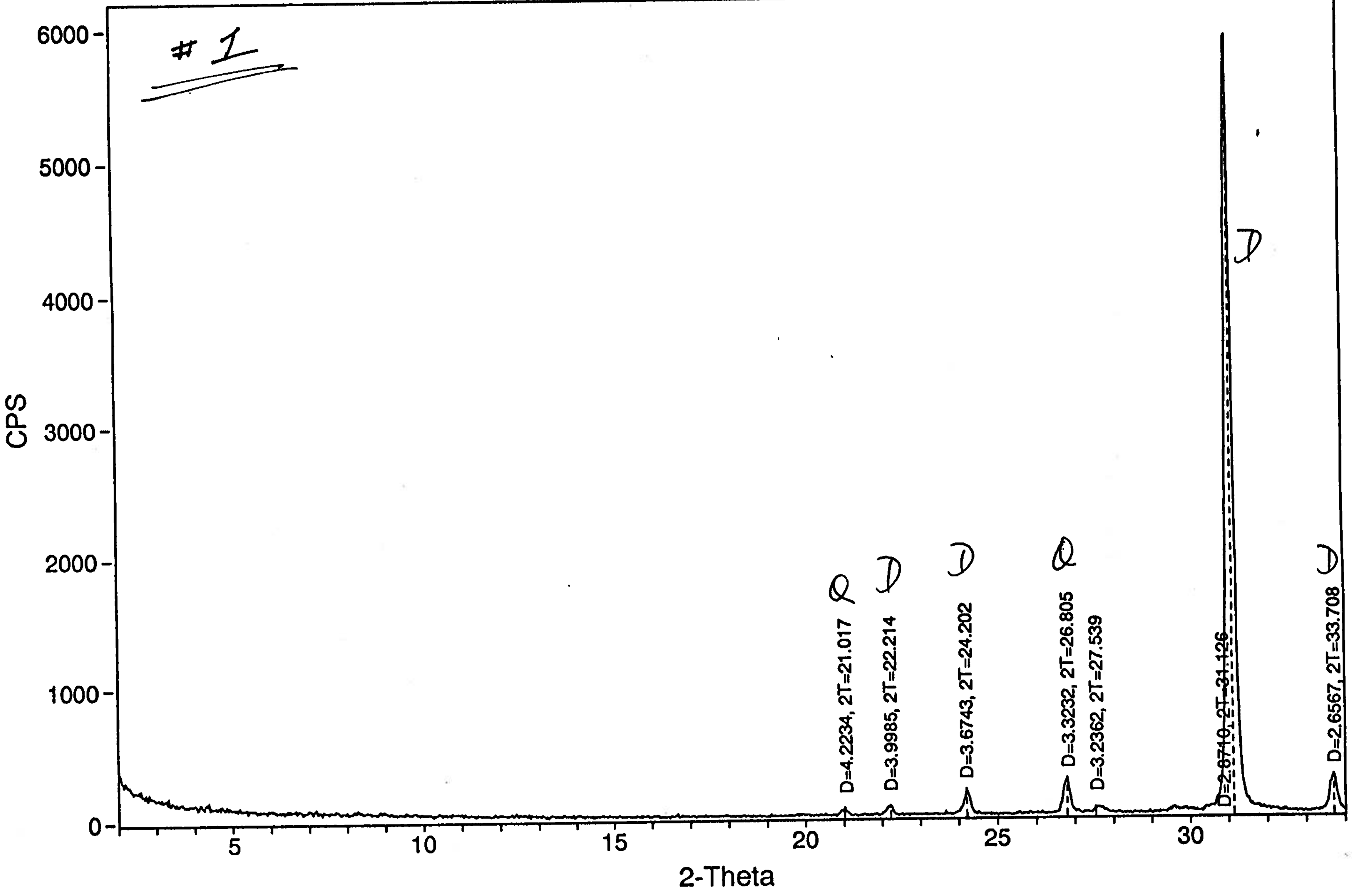

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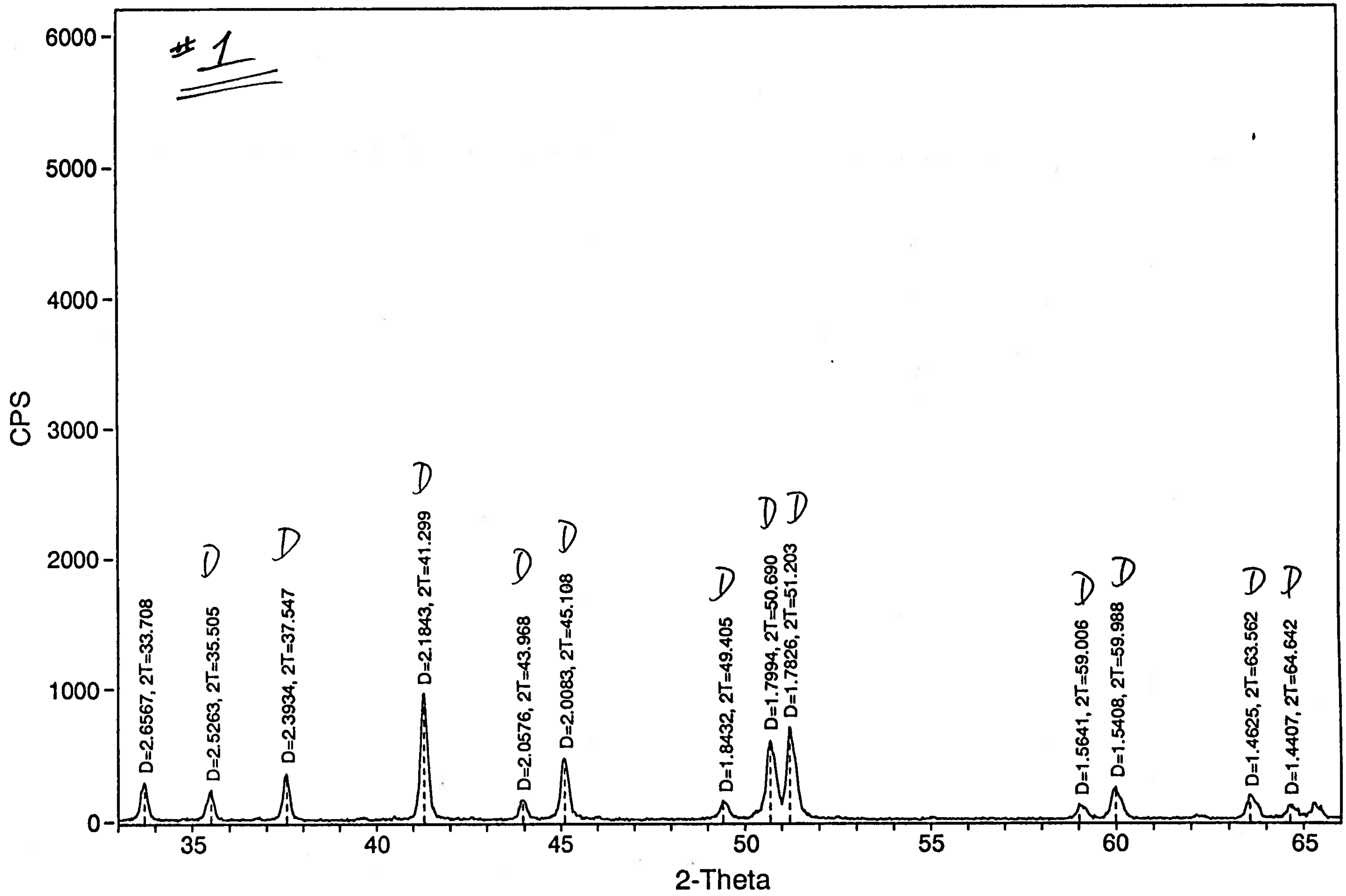

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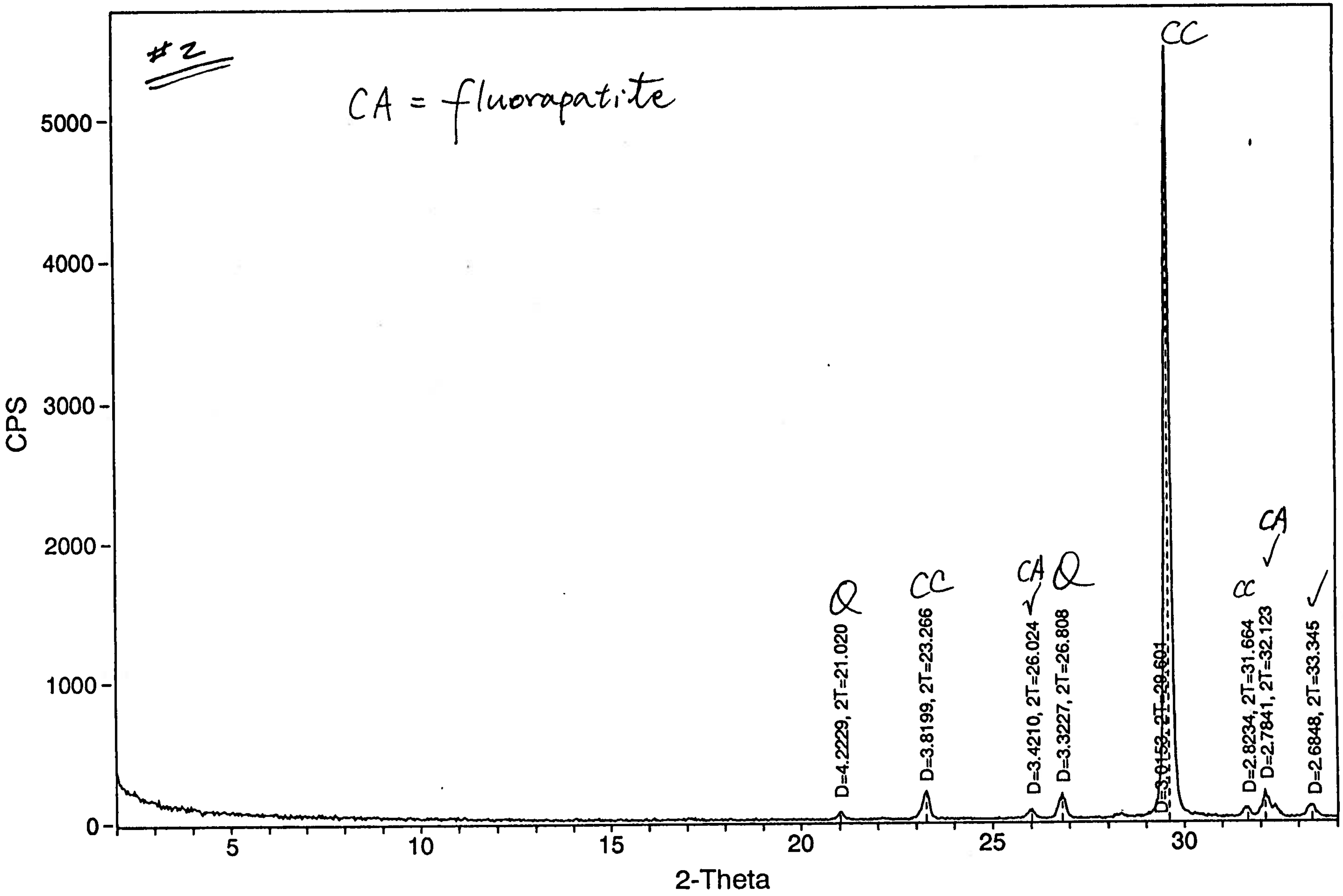

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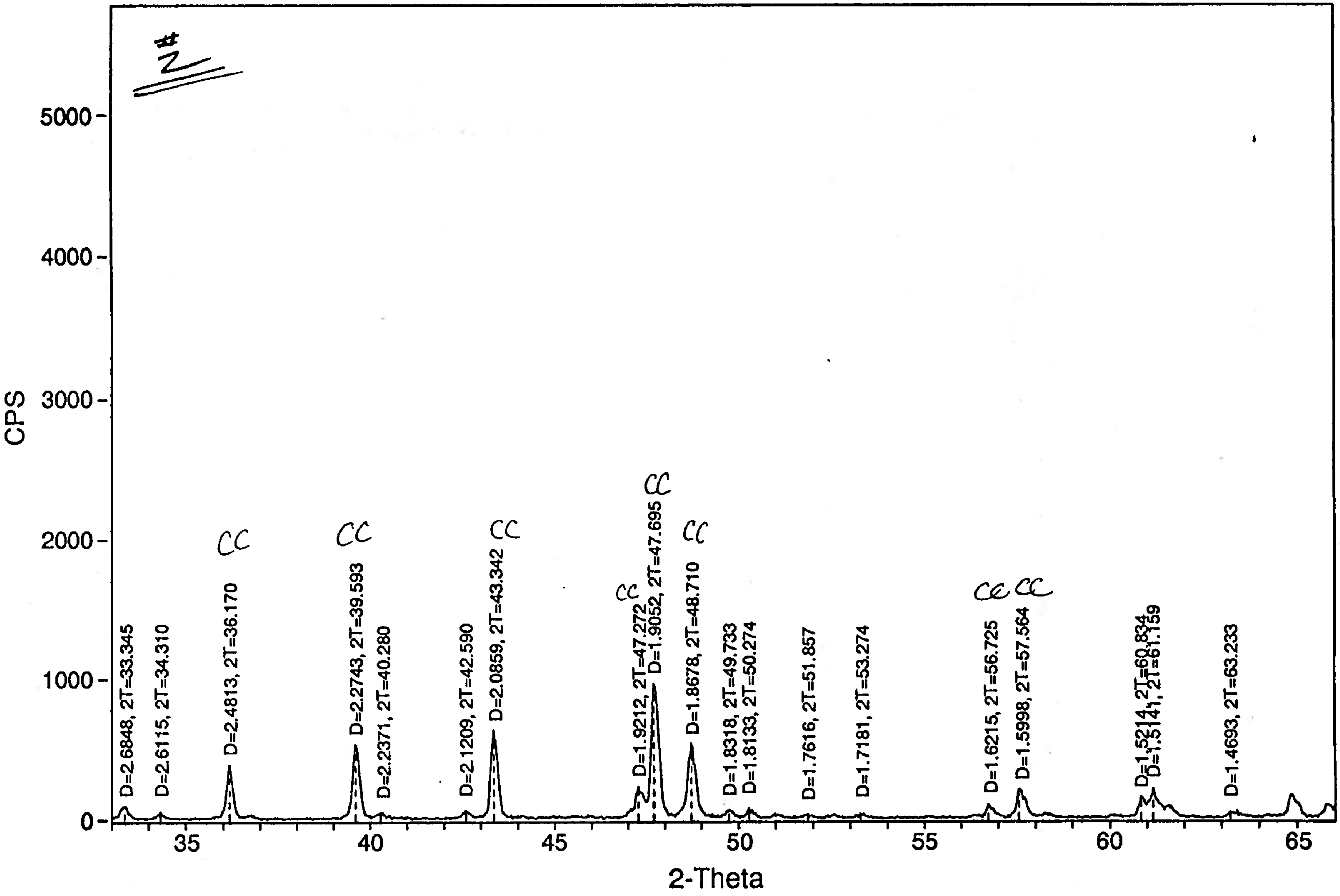

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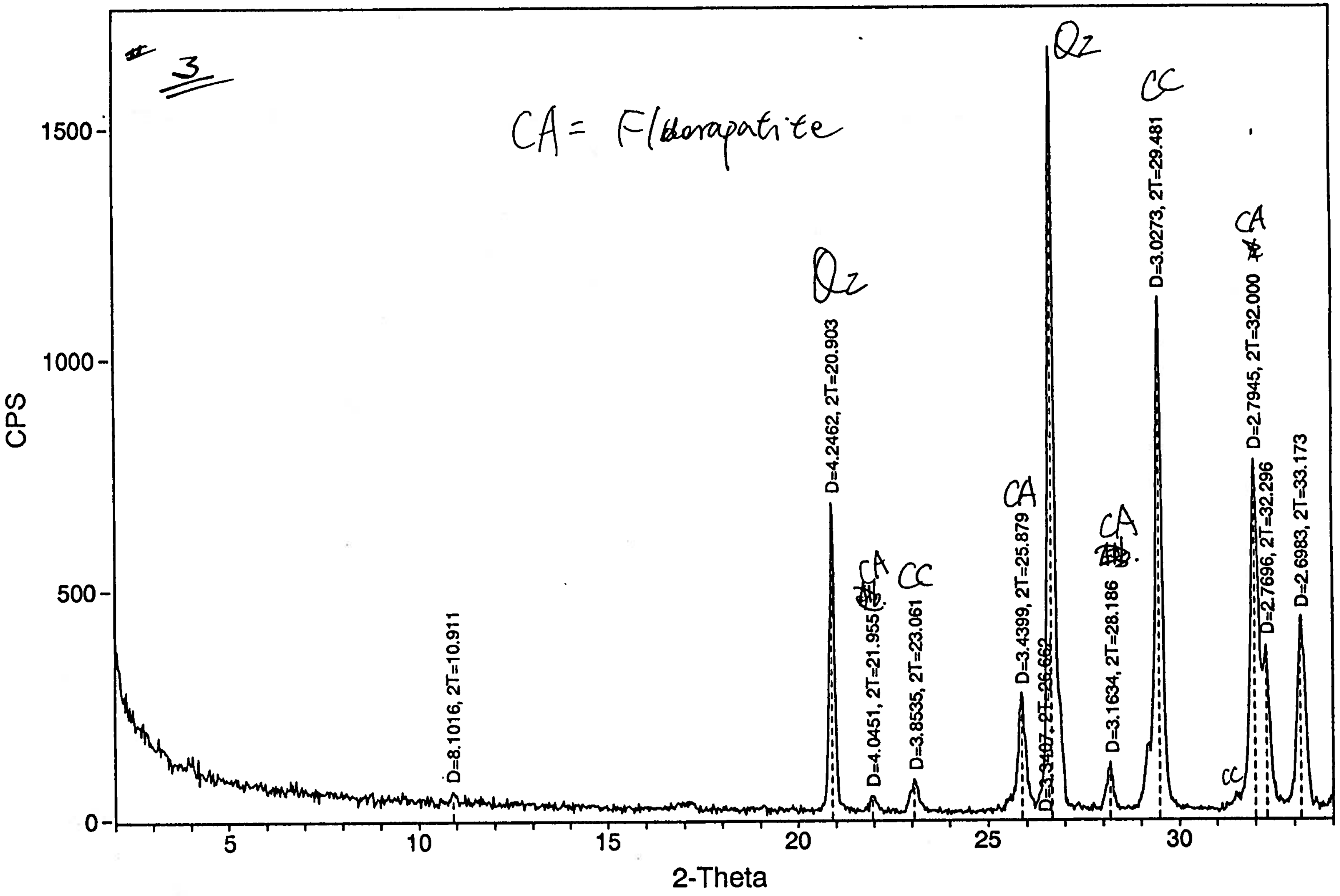

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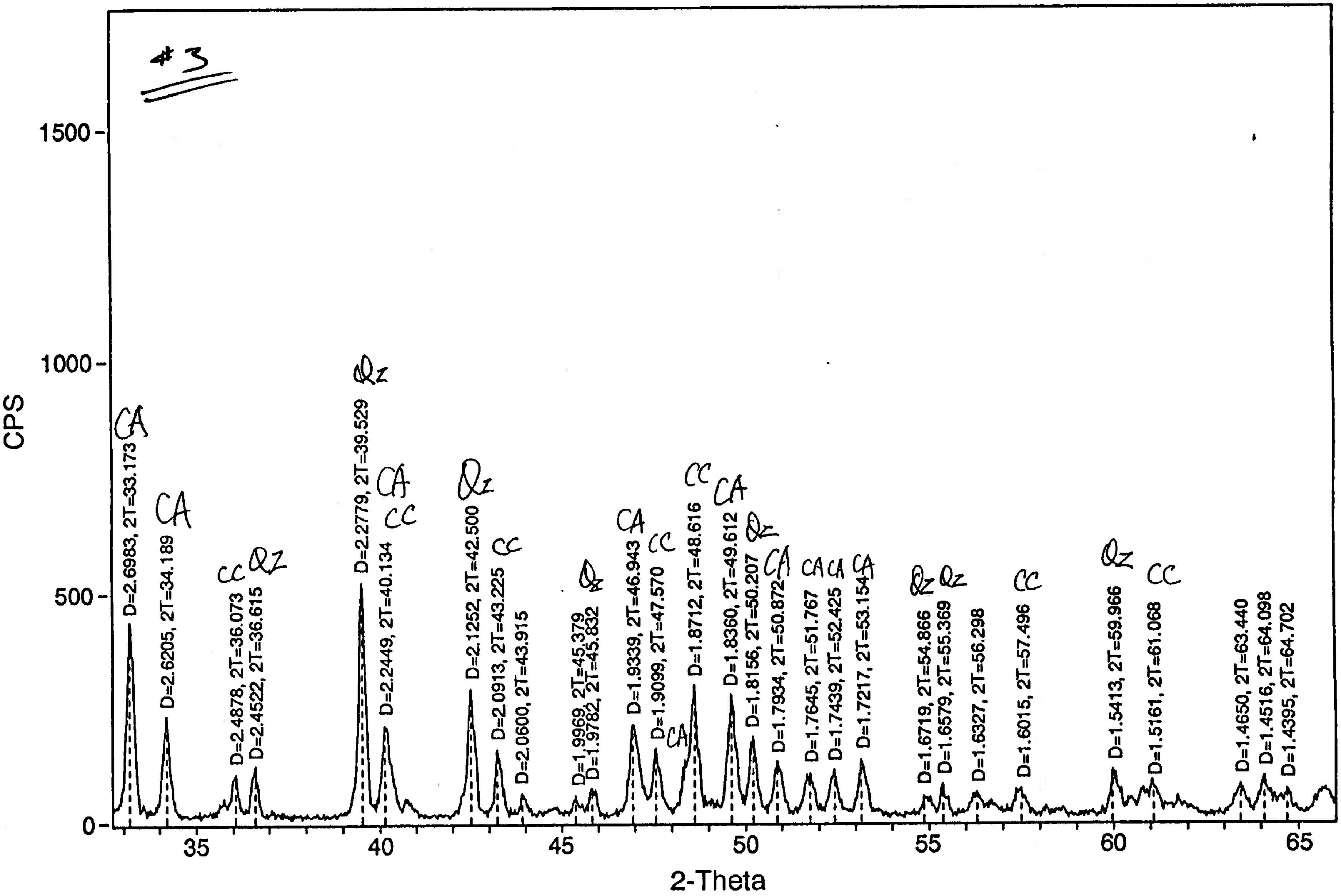

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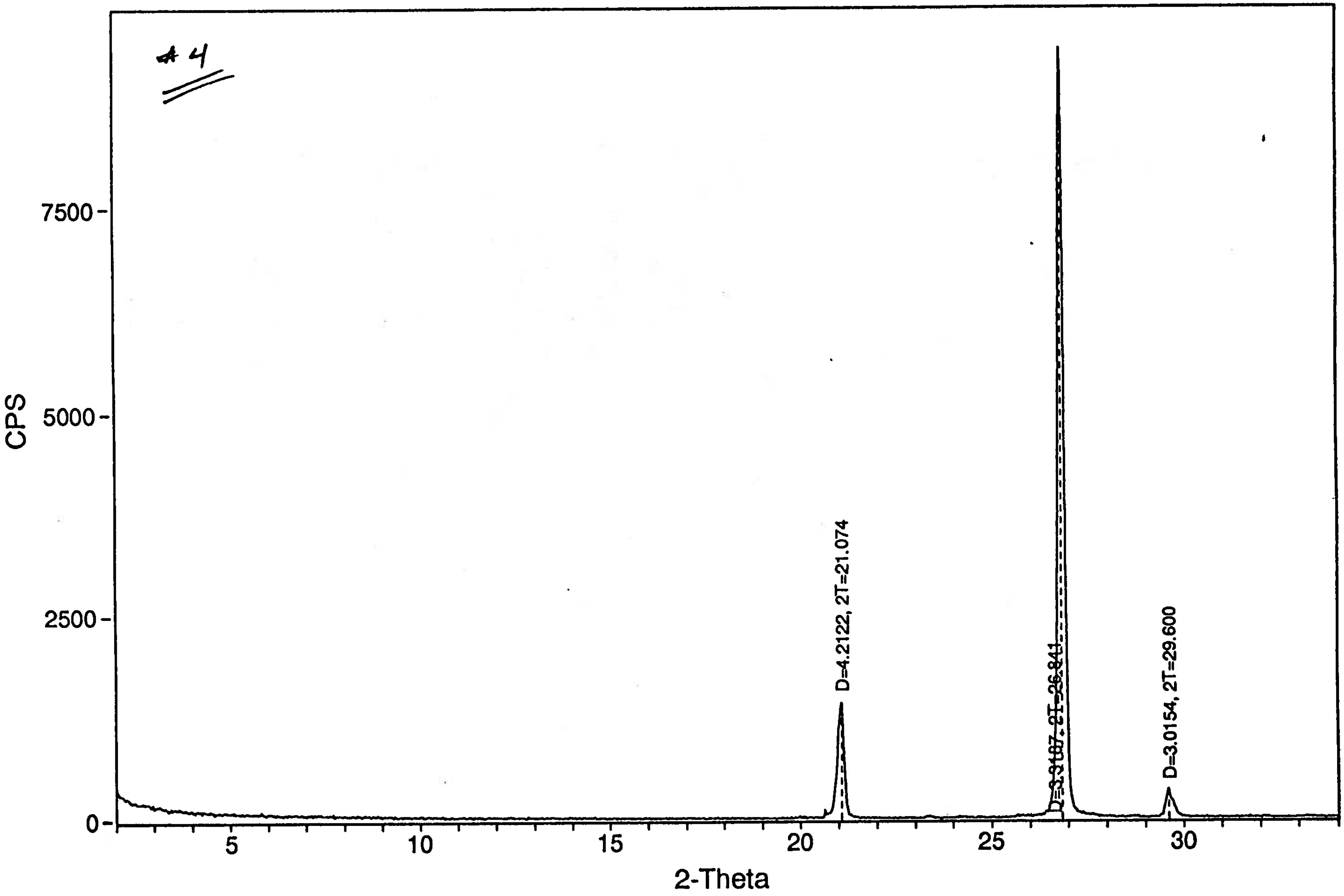

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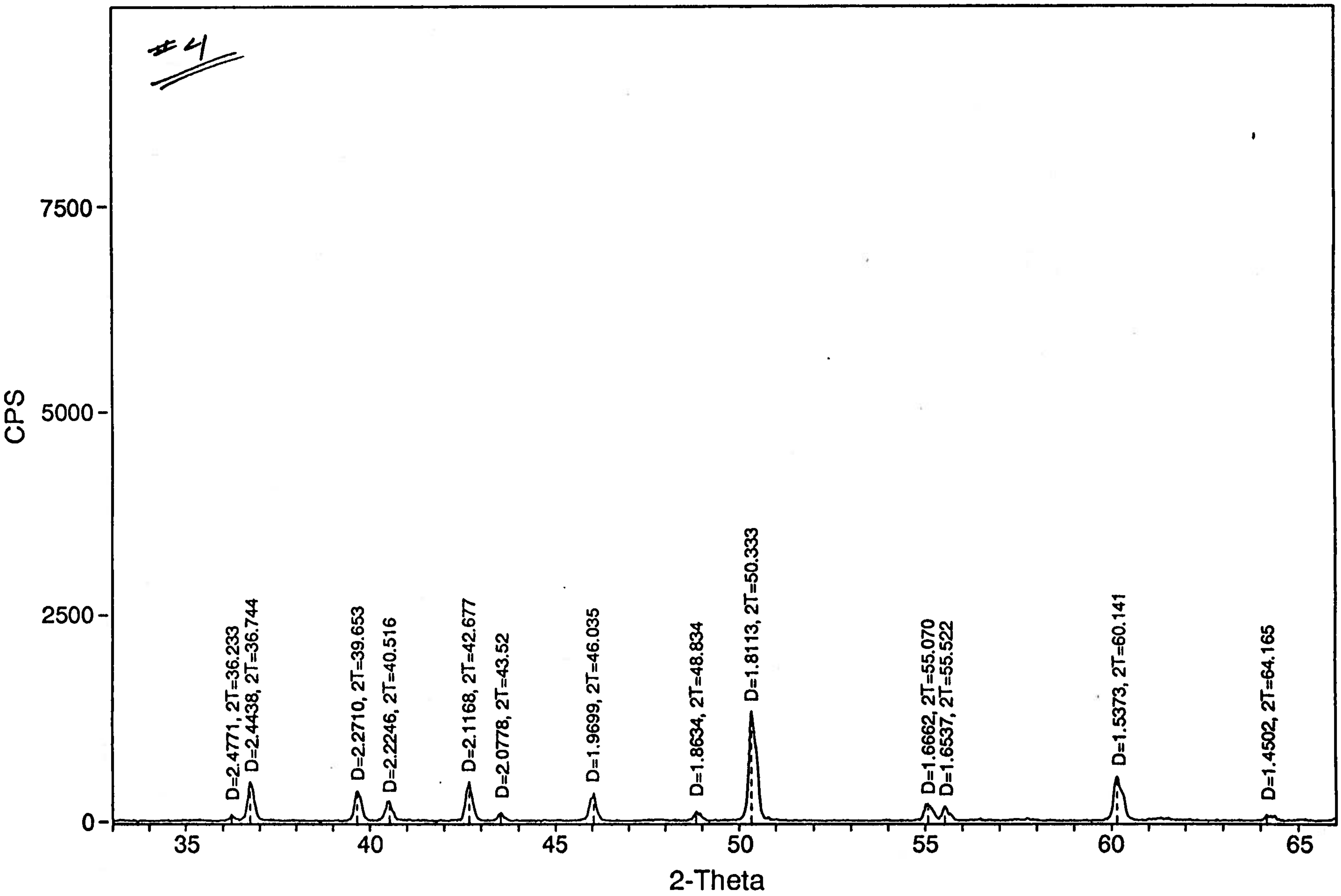

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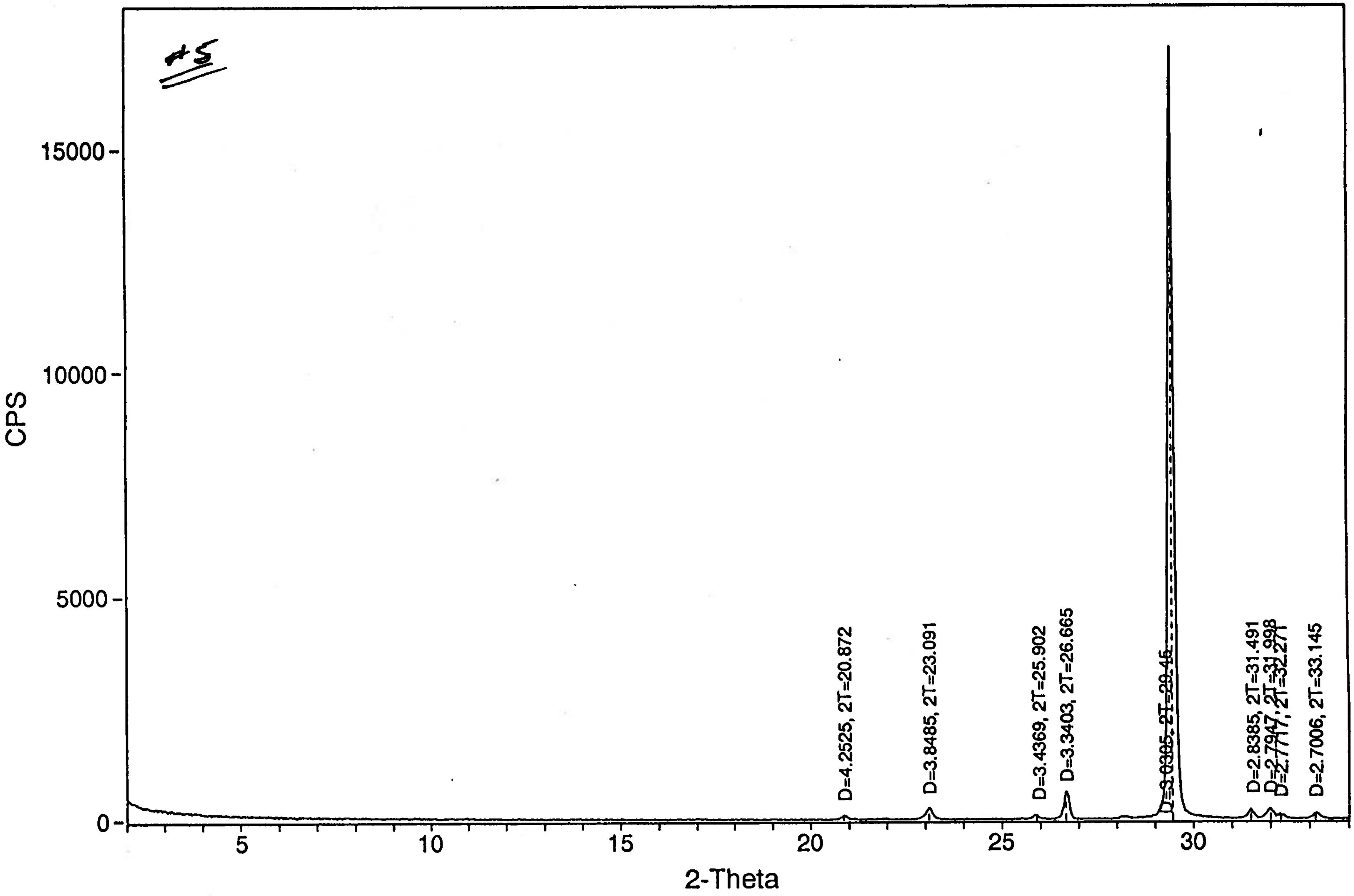

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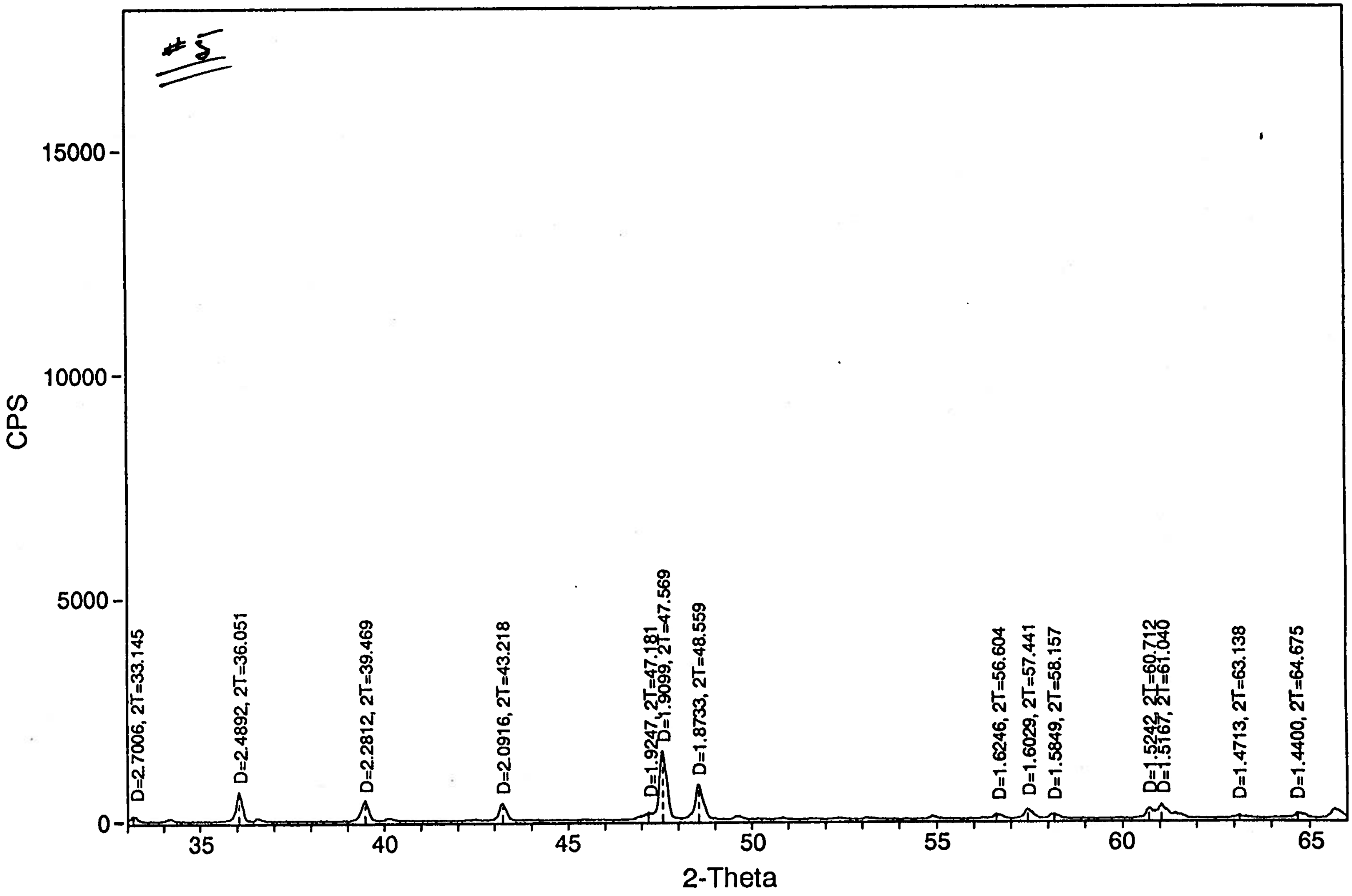

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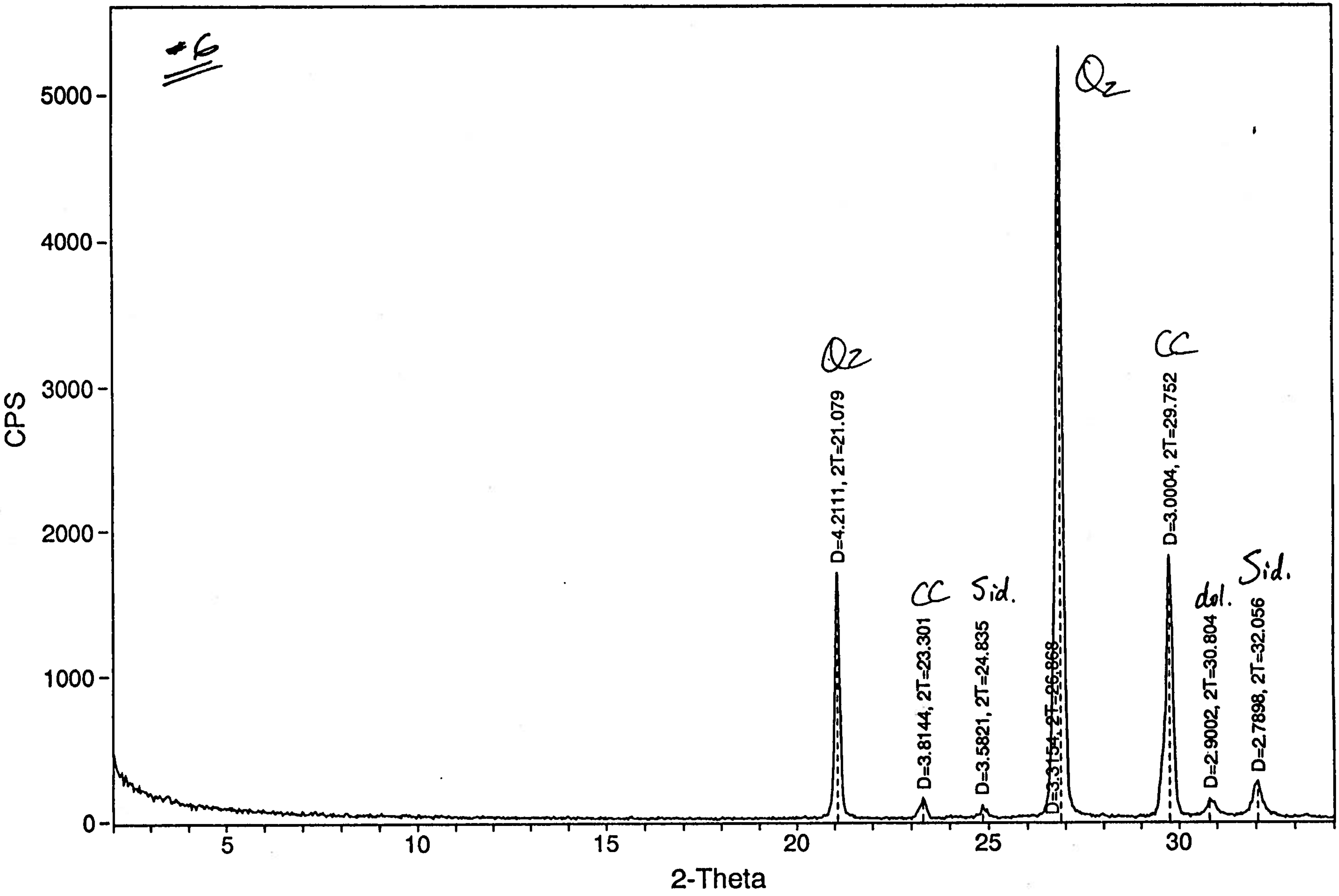

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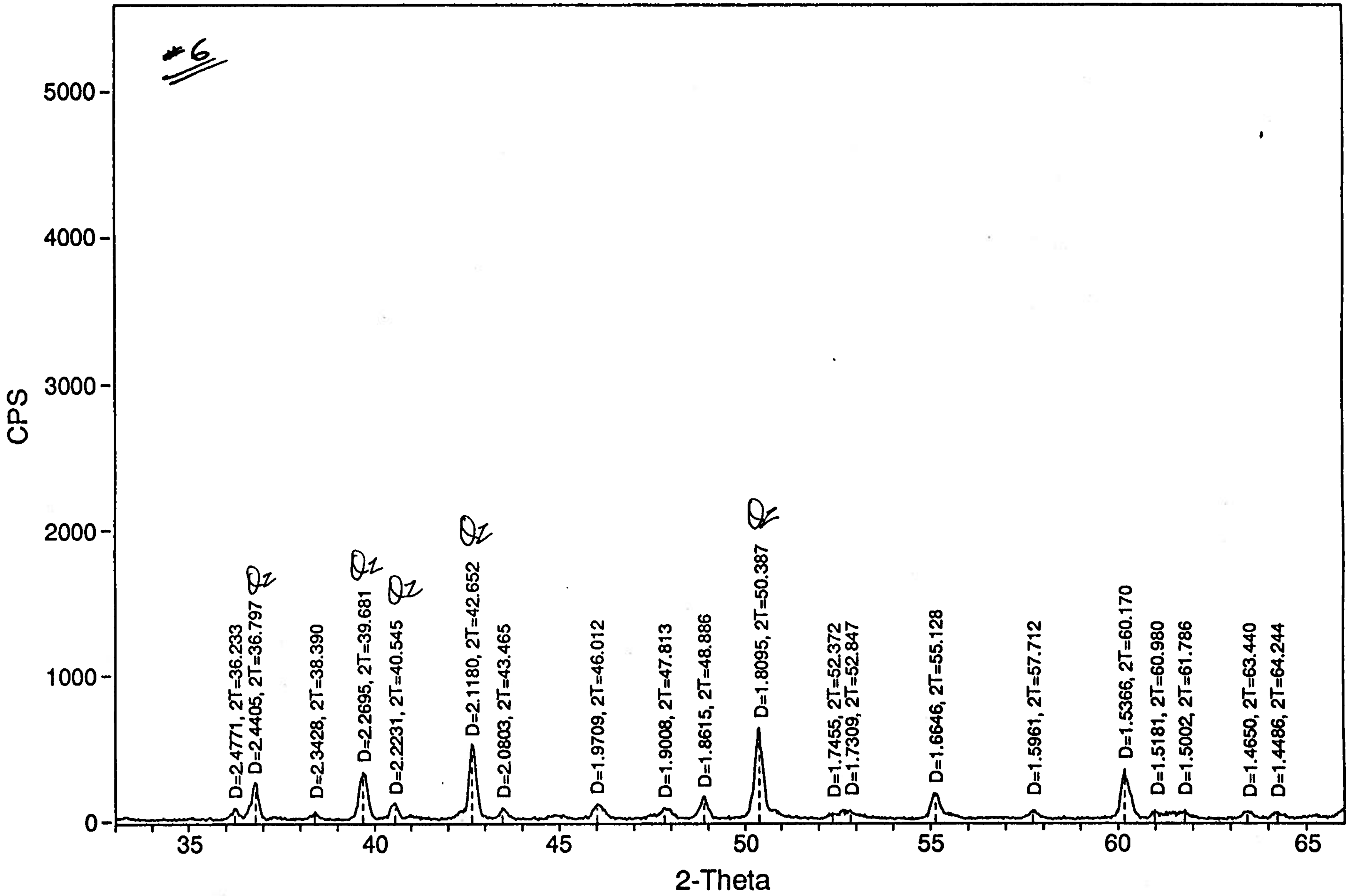

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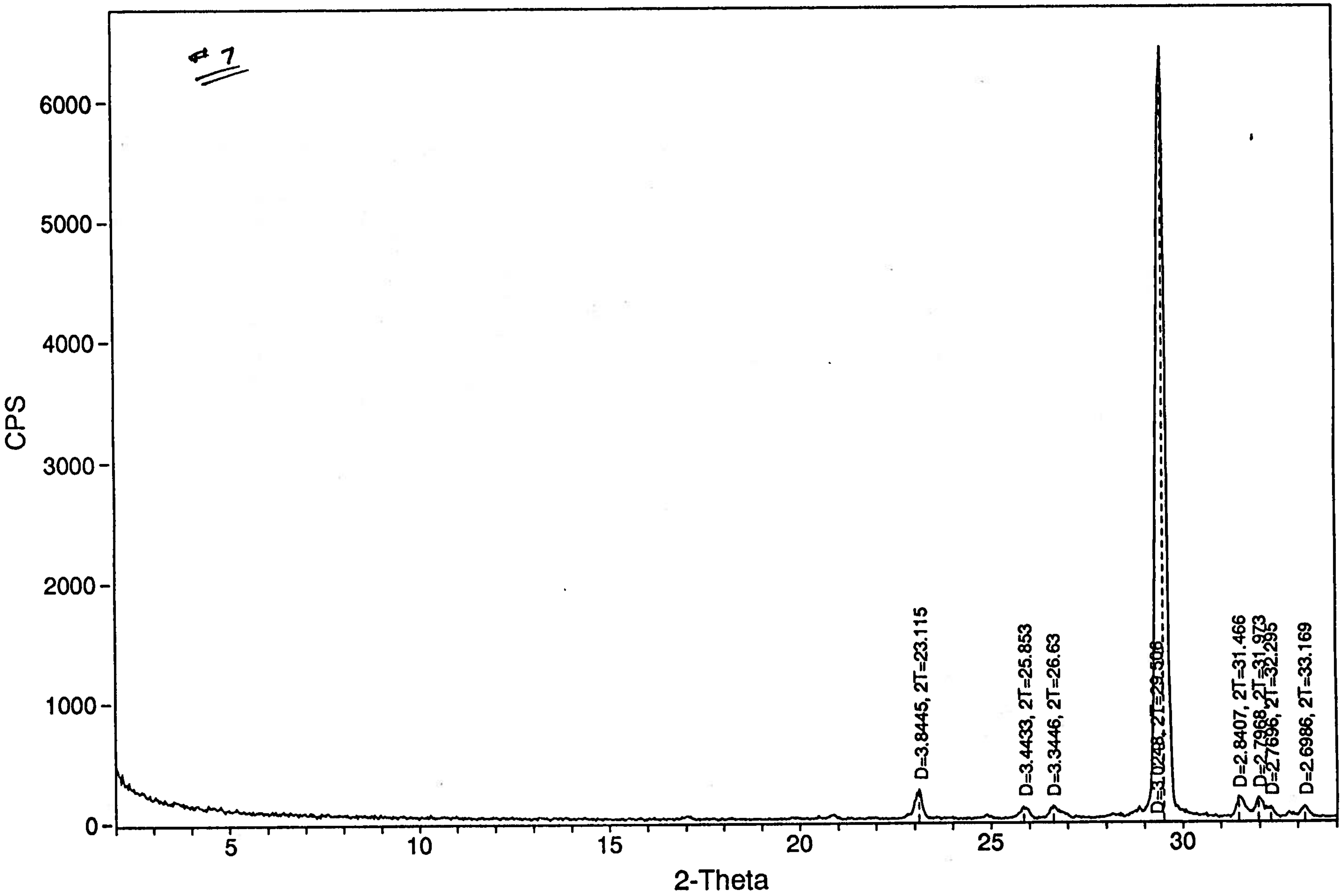

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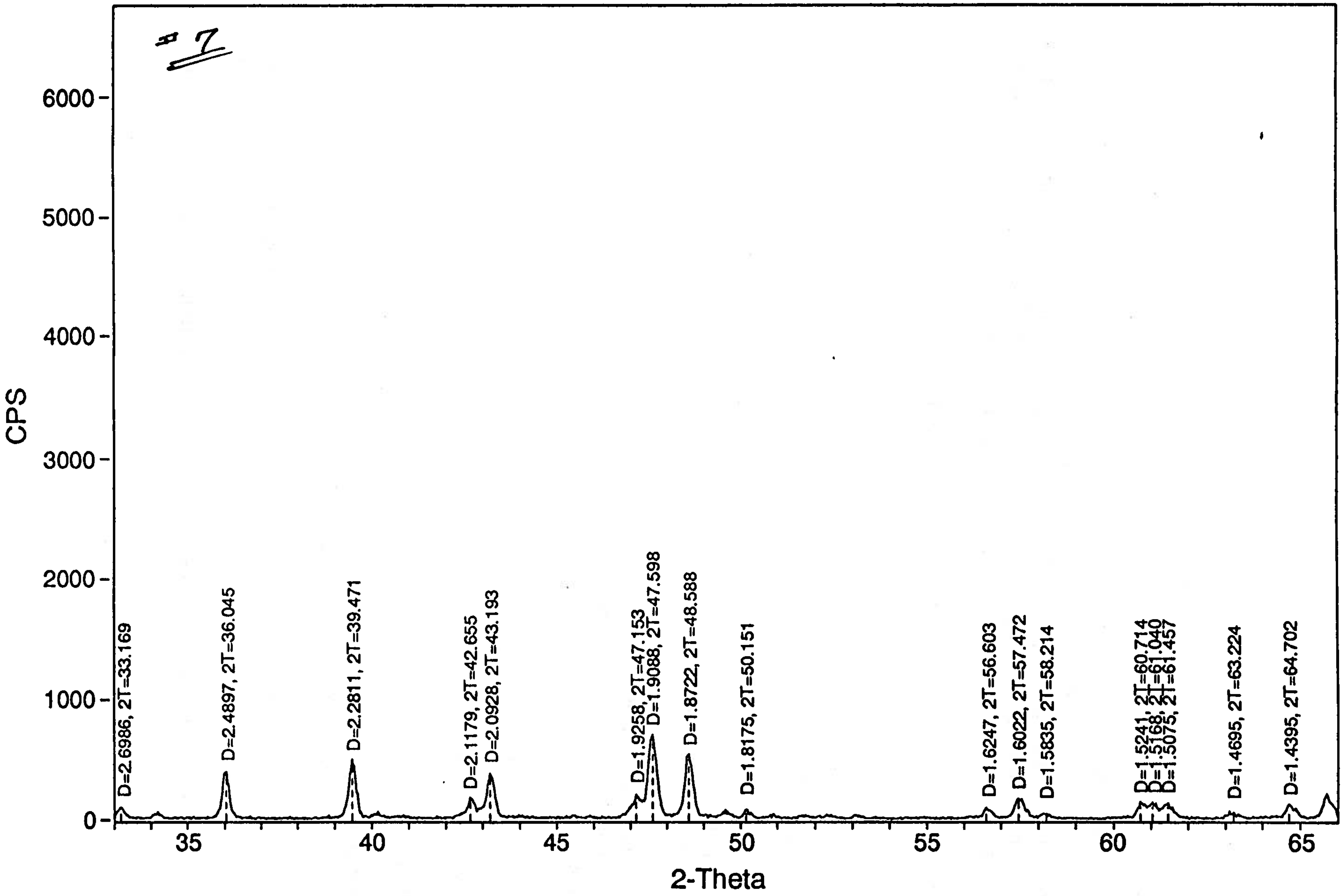
#7



APPENDIX 11.4.1

Thermal Aquifer Model Miscellaneous

The thermal aquifer model in STARS 4.0.2 is a semi-analytical used to calculate the water and energy flow between the outflow boundary of the discretized region in the numerical simulation and an adjacent aquifer. This flow is perpendicular to the outflow boundary. Since the numerical simulation is isothermal in this study, only the water flow is considered here. The model assumes the pressure profile as

$$P(t,r) = (P_{ob} - P_{ref} + a\,r + b\,r^2)\, e^{-r/d} + P_{ref} \qquad \text{(A.1)}$$

where

$$d = (\alpha\, t)^{0.5} / 2 \qquad \text{(A.2)}$$

$$\alpha = (\phi\, \mu\, c) / k \qquad \text{(A.3)}$$

a: fitting parameter,
b: fitting parameter,
c: compressibility of water,
d: diffusion length,
k: absolute permeability,
r: radial distance from outflow boundary,
P: pressure,
t: time,
α: diffusion coefficient,
ϕ: porosity,
μ: viscosity of water.

subscripts:

ob: value at outflow boundary,
ref: reference value at infinitive radial distance.

Beside the physical properties of the aquifer, the only unknowns in Equation (A.1) are a and b.

For a fluid of small compressibility such as water, the governing flow equation in linear flow is:

$$\partial P/\partial t = \alpha\, (\partial^2 P / \partial r^2) \qquad \text{(A.4)}$$

Equation (A.4) must be satisfied at the outflow boundary $(r = 0)$. Insertion of Equation (A.1) into Equation (A.4) with the derivative of pressure at $r = 0$ together with a finite-differnece discretization of the time derivative gives the first equation for solving a and b. The conservation of water flow can be satisfied by integrating Equation (A.4) from 0 to infinity assuming α as a constant. This gives the second equation for solving a and b.

The rate per unit area at which water flows from the outflow boundary is:

$$-\lambda \; (\partial P / \partial r) \,\big|_{r=0} = -\lambda \; (a \; - \; P_{ob} / d) \qquad \text{(A.5)}$$

where λ is the fluid transmissibility and is defined as:

$$\lambda \; = \; k / \mu \qquad \text{(A.6)}$$

APPENDIX 11.5.a

Graphs Generated from PATH.UBC output

Figure 11.5.1

Reaction of Brackish Formation Water with CO_2 at 25°C as it is injected into the aquifer; plotted as a function of time ('XI').

a: Buildup of the partial pressure of CO_2 in bars.

b: Molar amount of CO_2 injected into the aquifer.

c: Change in the molality of the aqueous species.

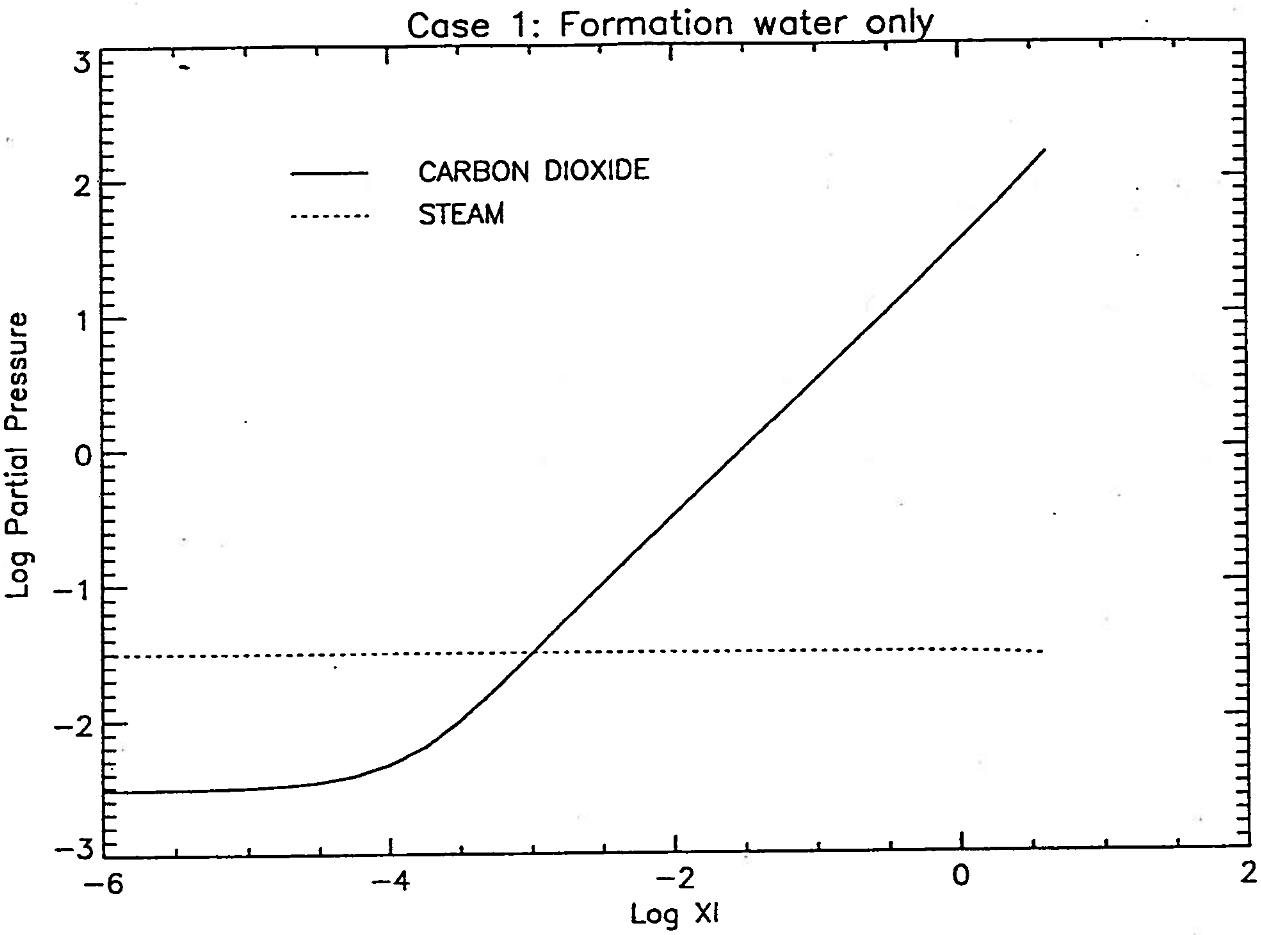


Figure 11.5.1a

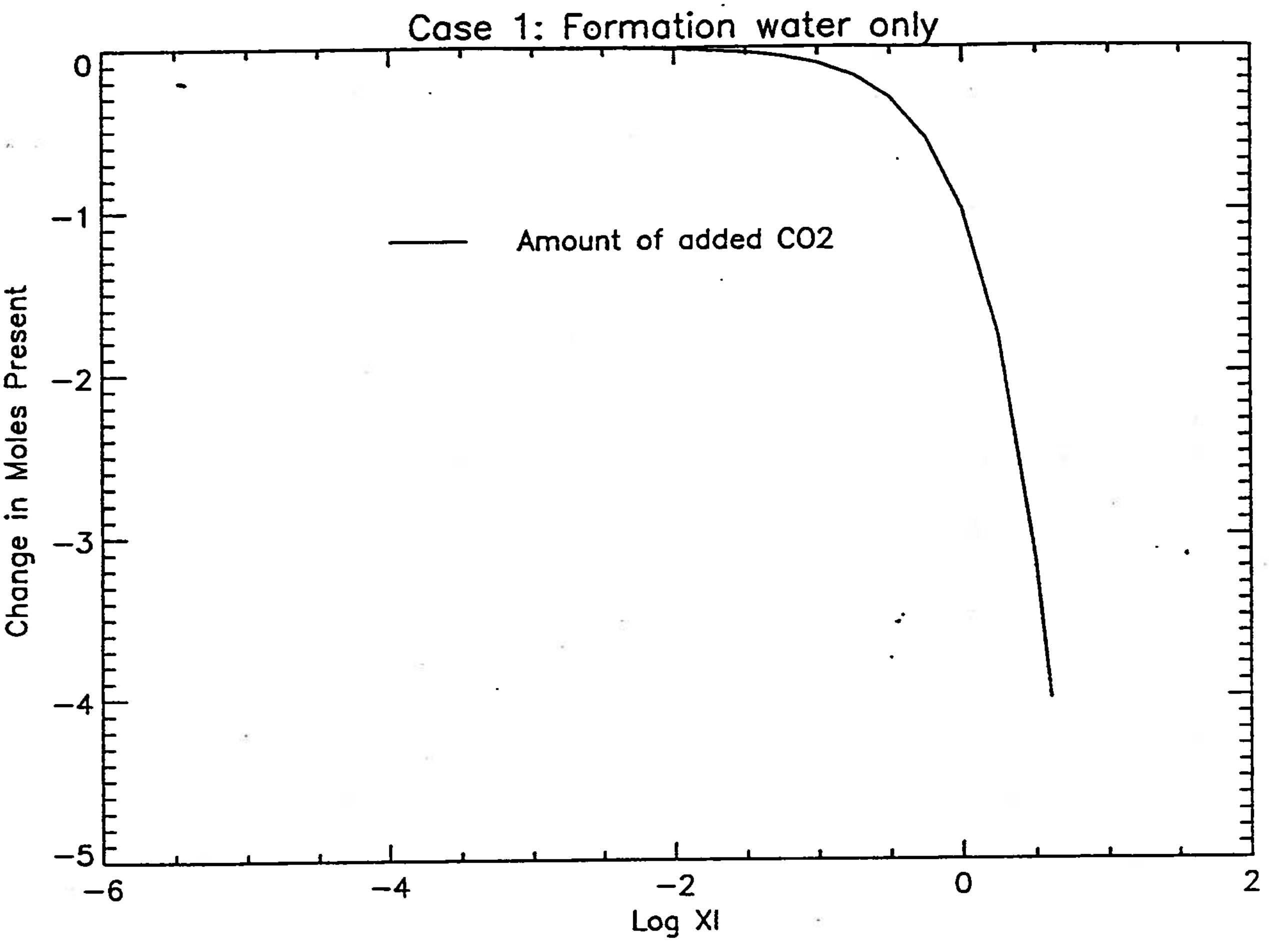


Figure 11.5.1b

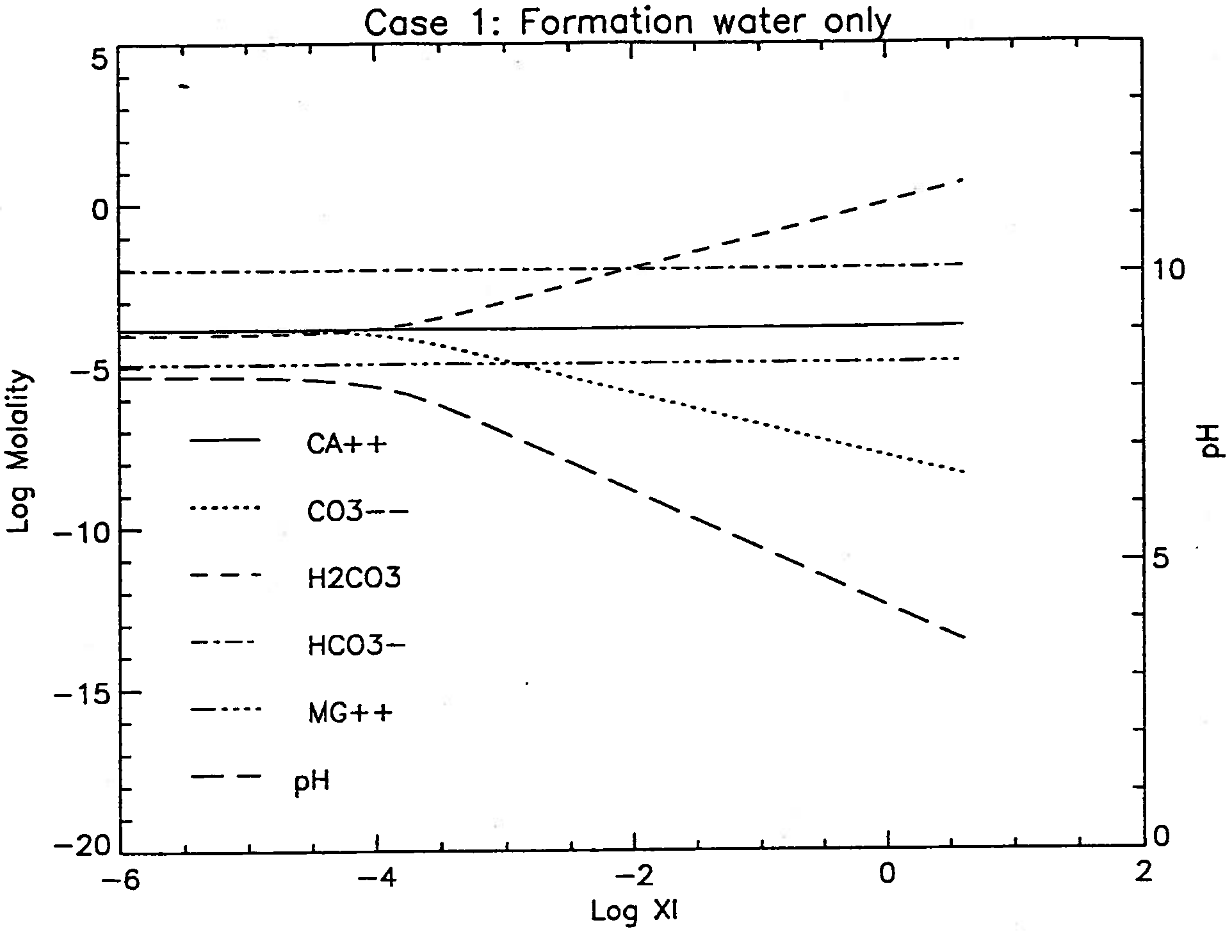


Figure 11.5.1c

Figure 11.5.2

Reaction of a Formation Water Brine with CO_2 at 25°C as it is injected into the aquifer; plotted as a function of time ('XI').

a: Buildup of the partial pressure of CO_2 in bars.

b: Molar amount of CO_2 injected into the aquifer.

c: Change in the molality of the aqueous species.

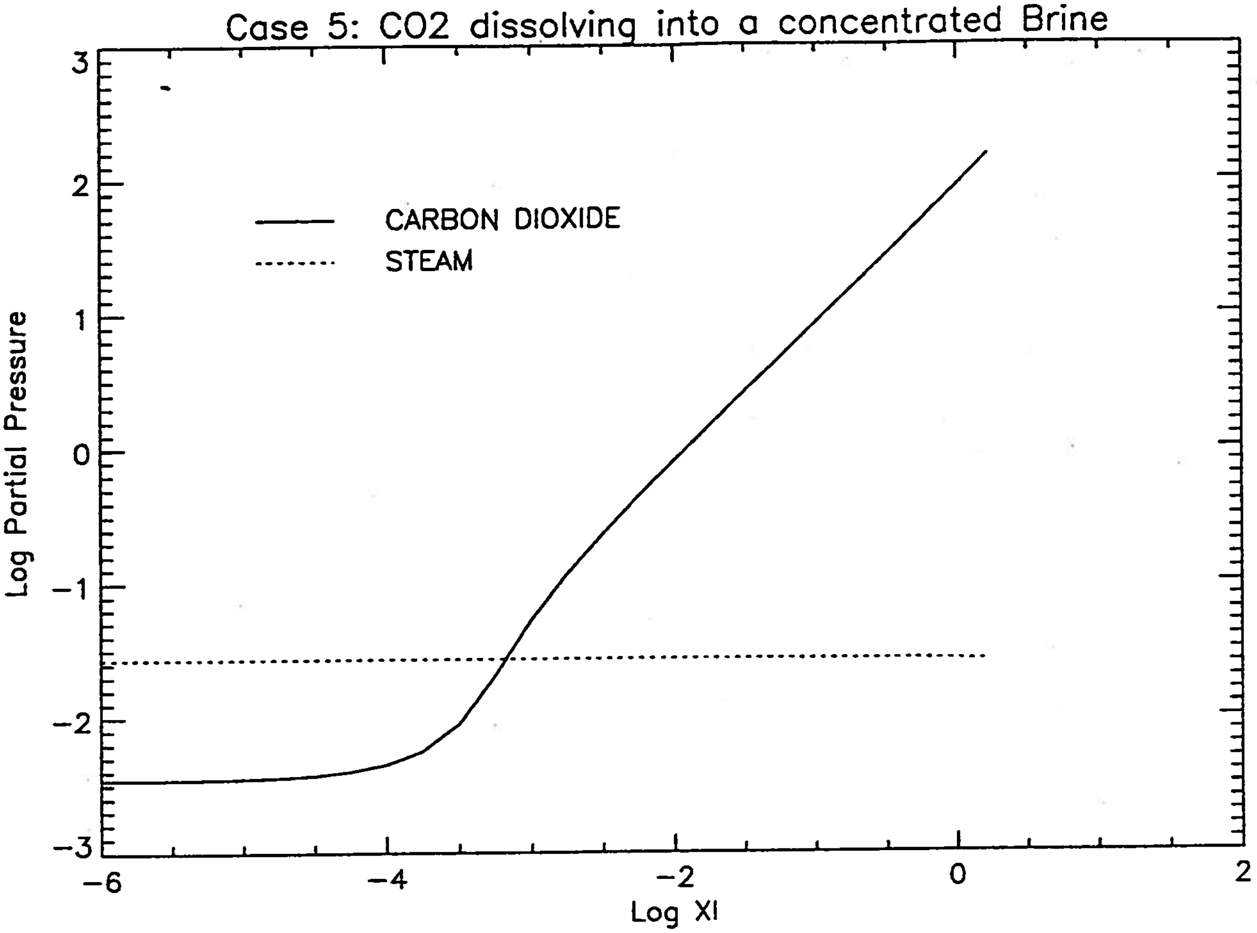


Figure 11.5.2a

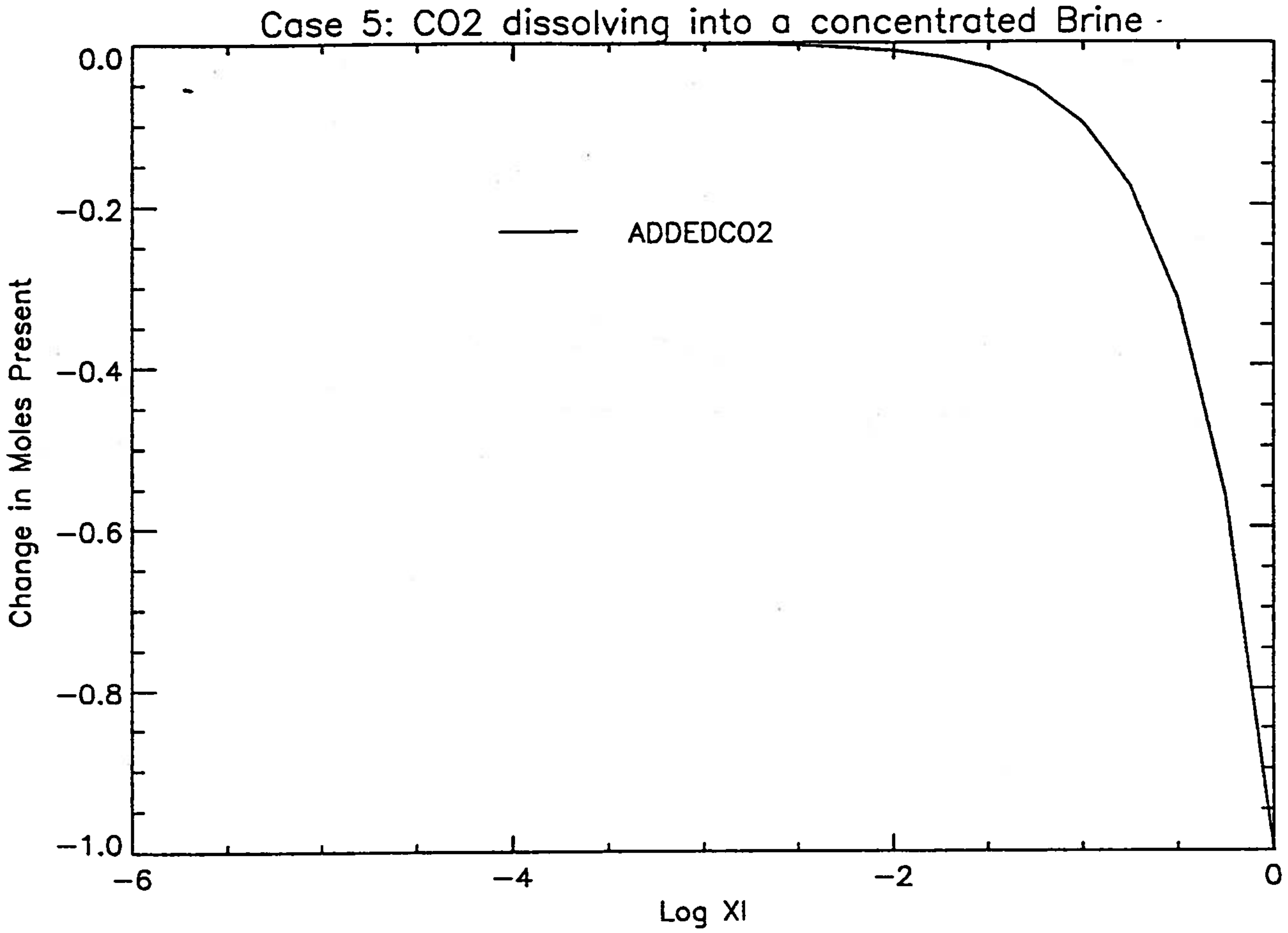


Figure 11.5.2b

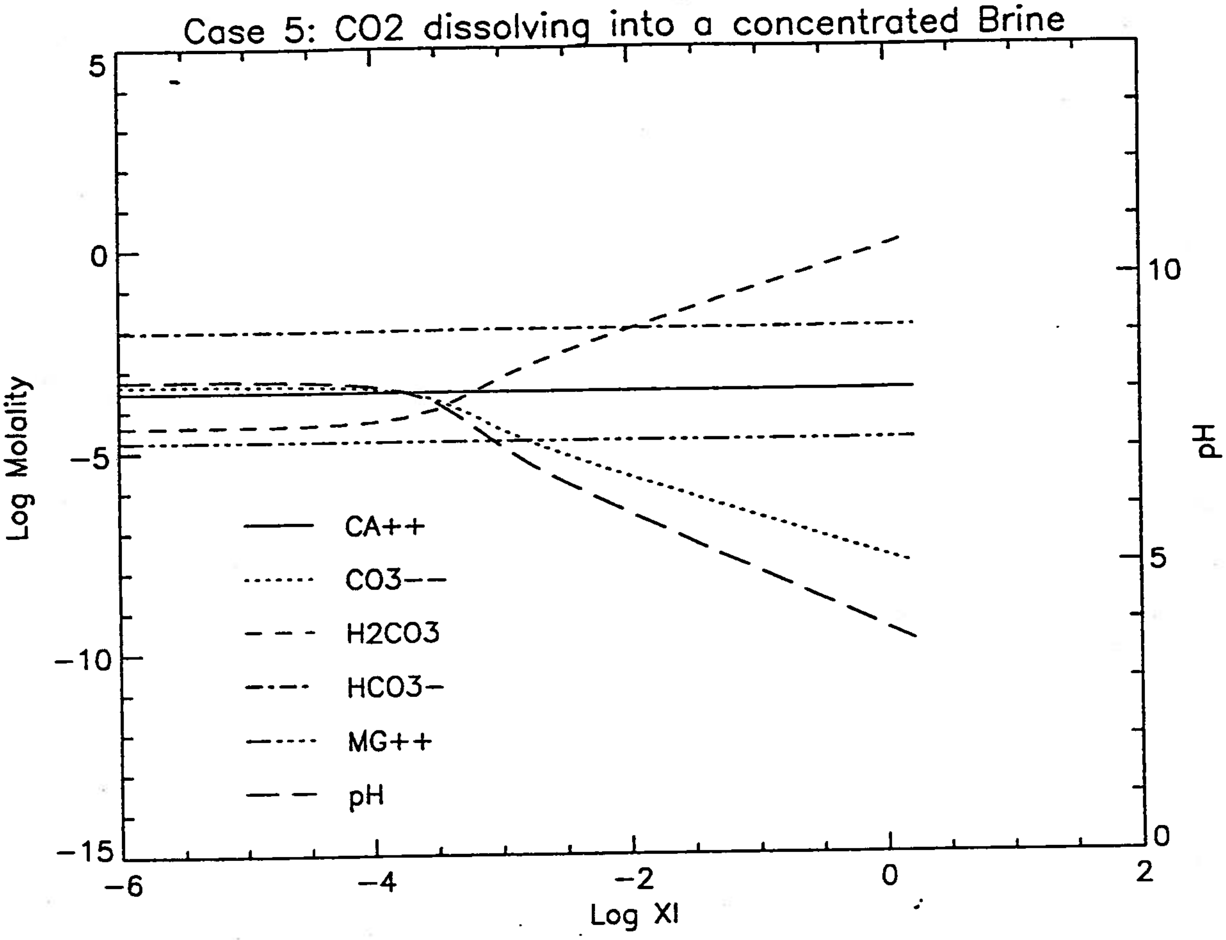


Figure 11.5.2c

Figure 11.5.3

Reaction of Brackish Formation Water with a calcite-dolomite limestone aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

a: Buildup of the partial pressure of CO_2 in bars.

b1: Molar amount of CO_2 injected into the aquifer.

b2: Change in the moles of mineral reactants.

c: Change in the molality of the aqueous species.

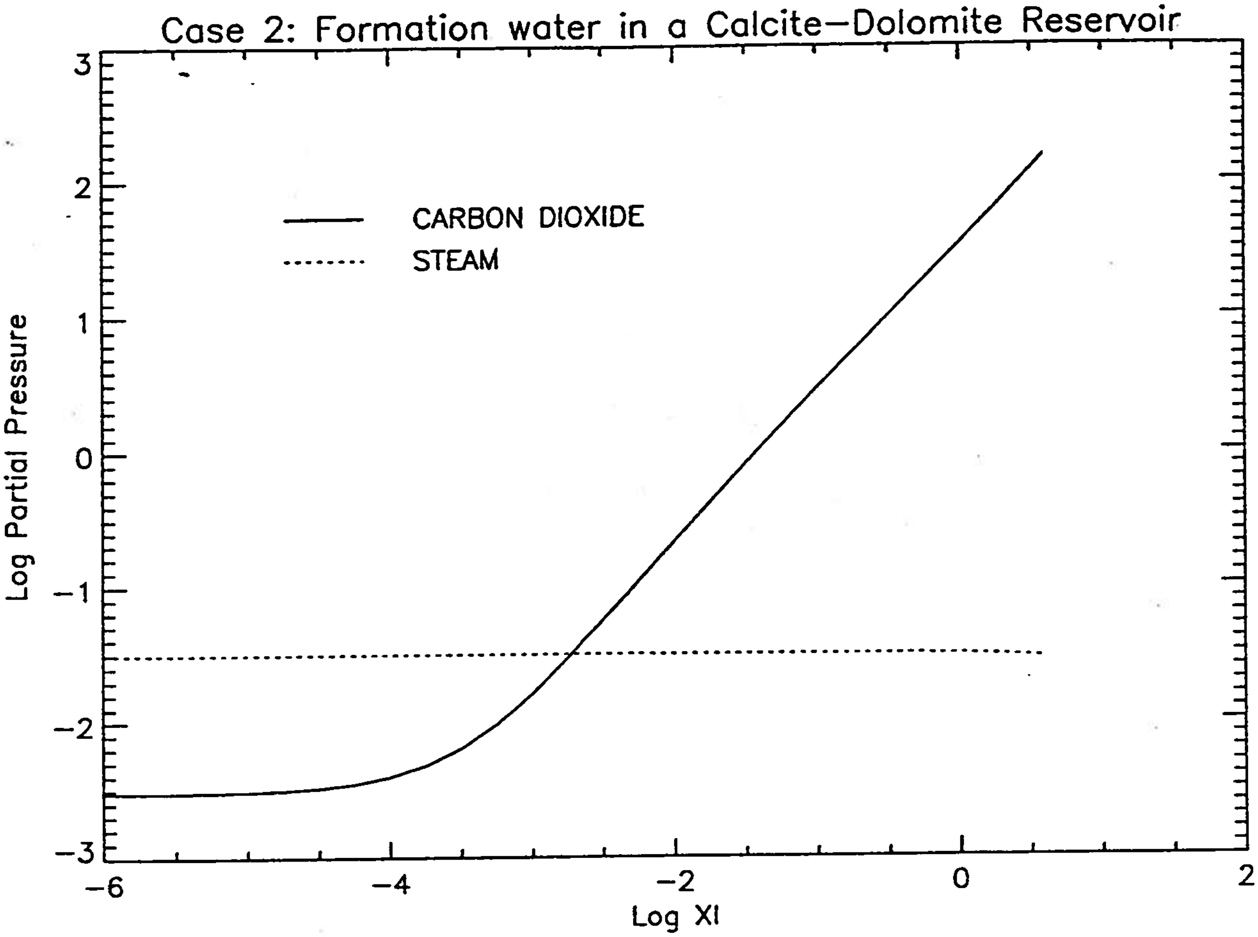


Figure 11.5.3a

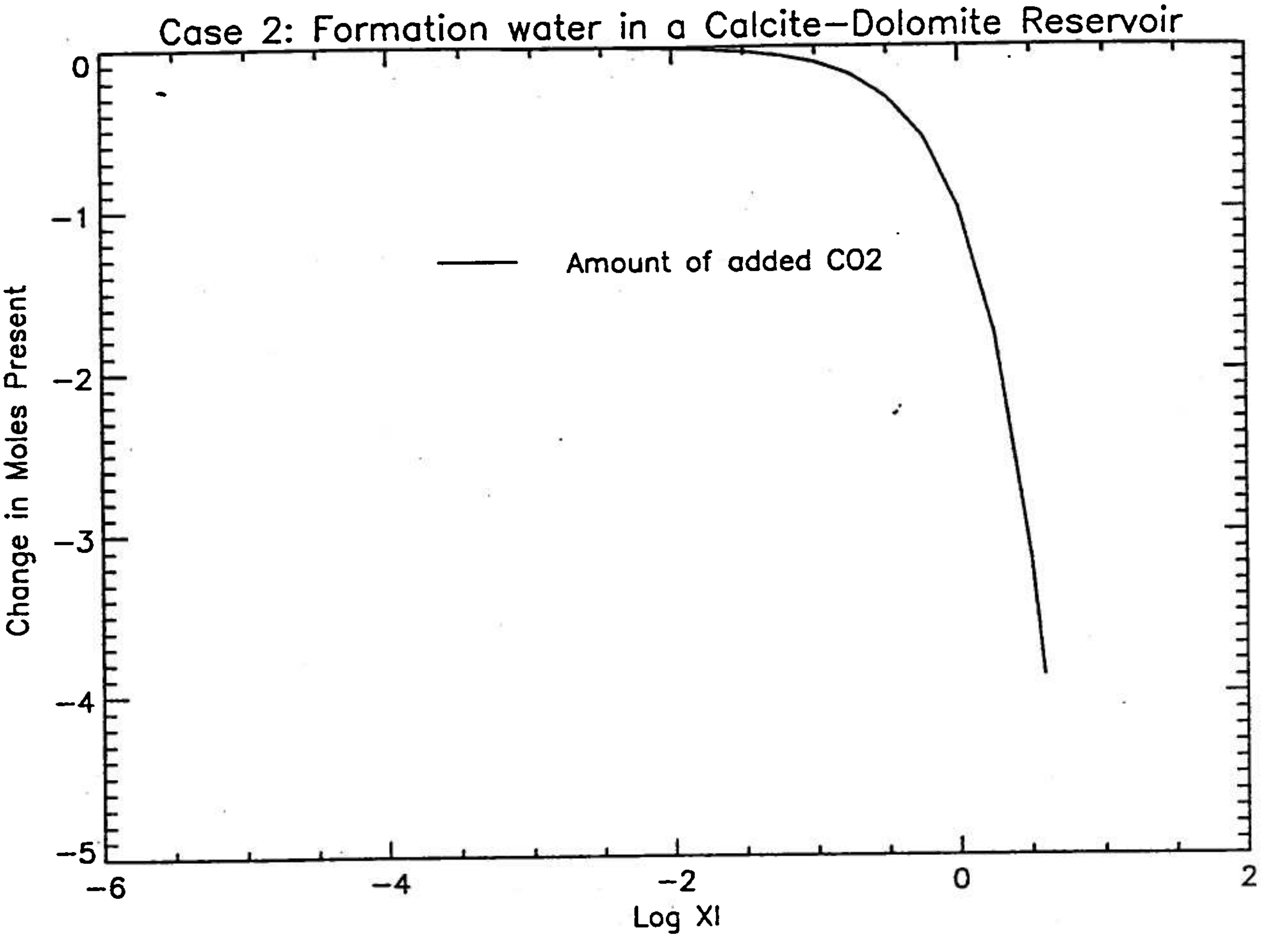


Figure 11.5.3b1

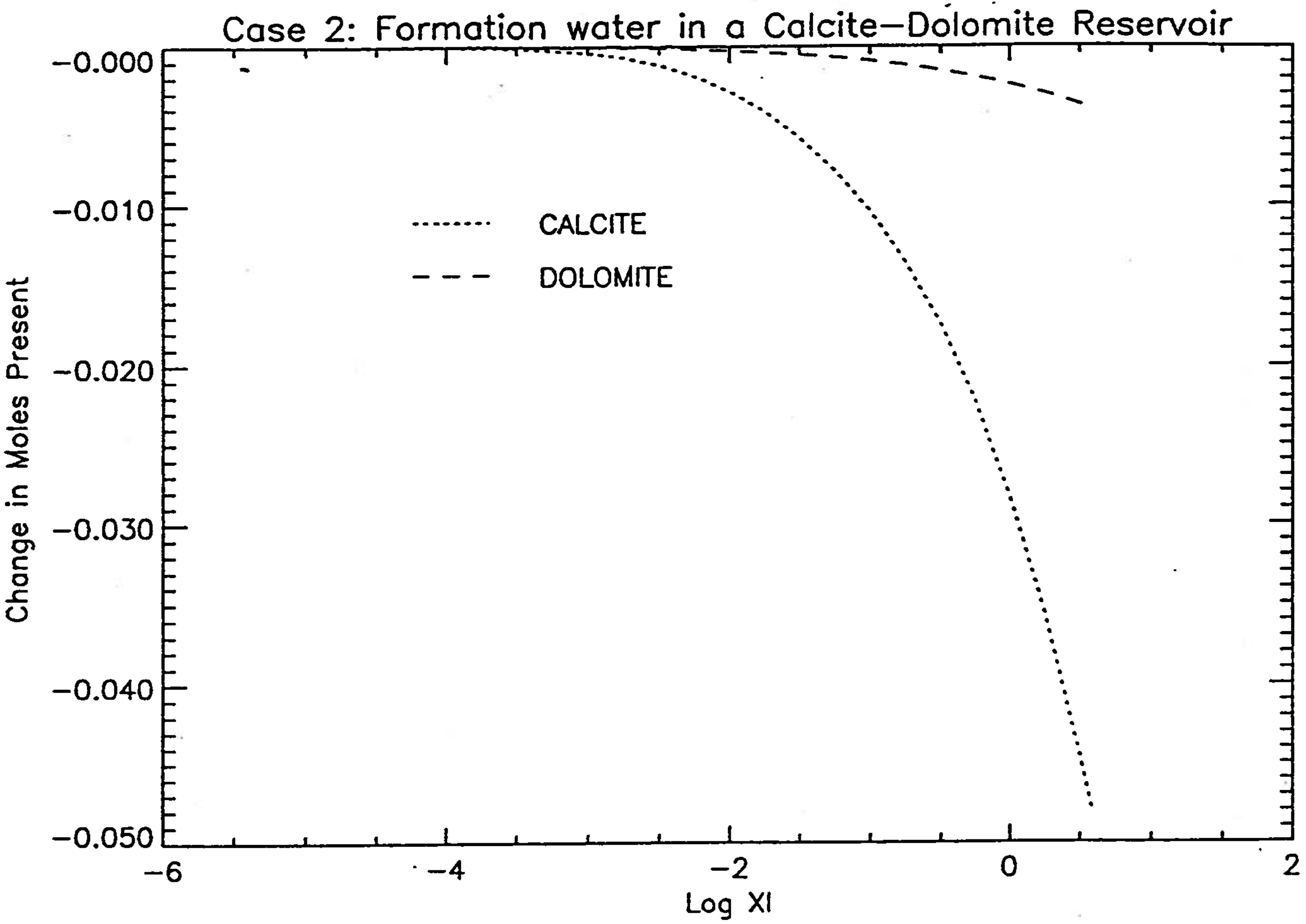


Figure 11.5.3b2

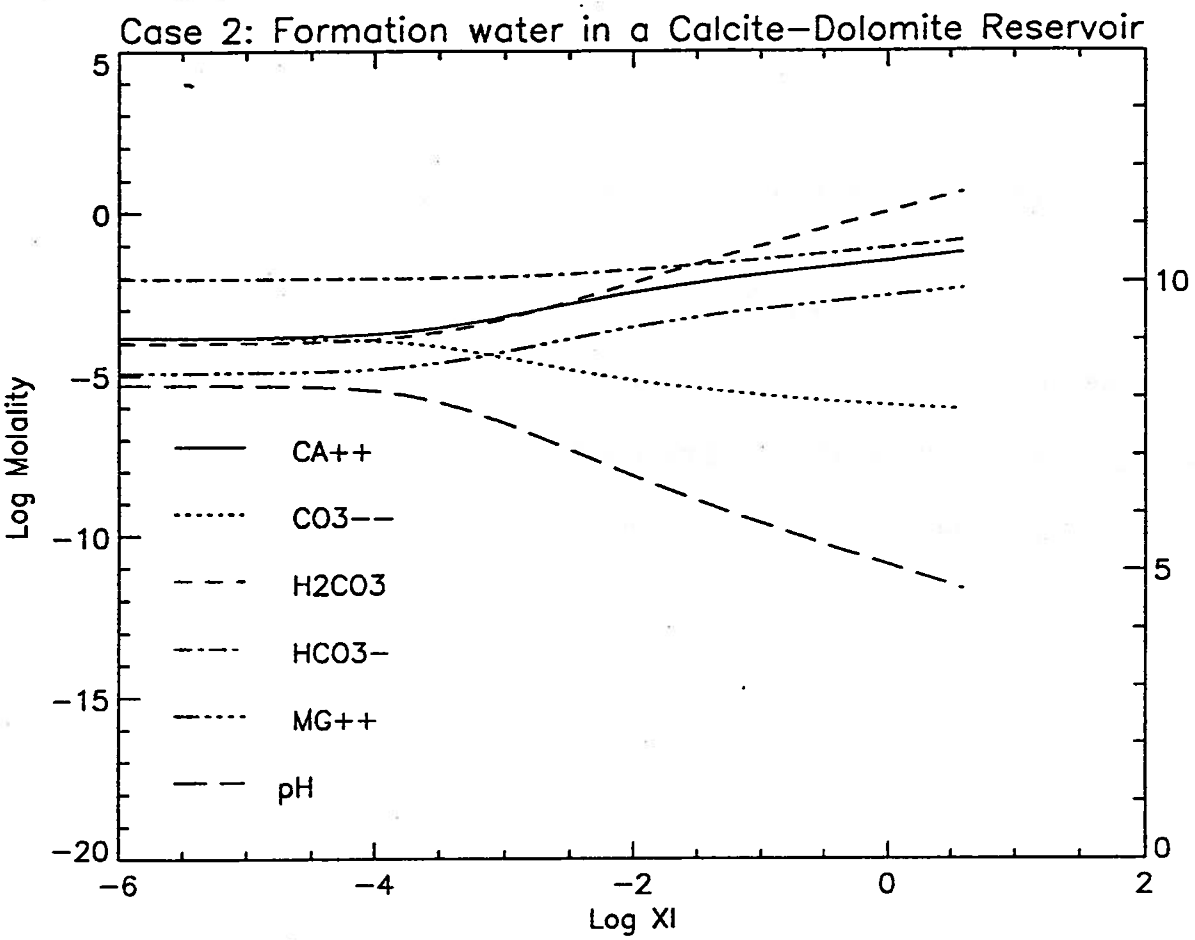


Figure 11.5.3c

Figure 11.5.4

Reaction of Brackish Formation Water with a calcite-dolomite-quartz limestone aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

a: Buildup of the partial pressure of CO_2 in bars.

b1: Molar amount of CO_2 injected into the aquifer.

b2: Change in the moles of mineral reactants.

c: Change in the molality of the aqueous species.

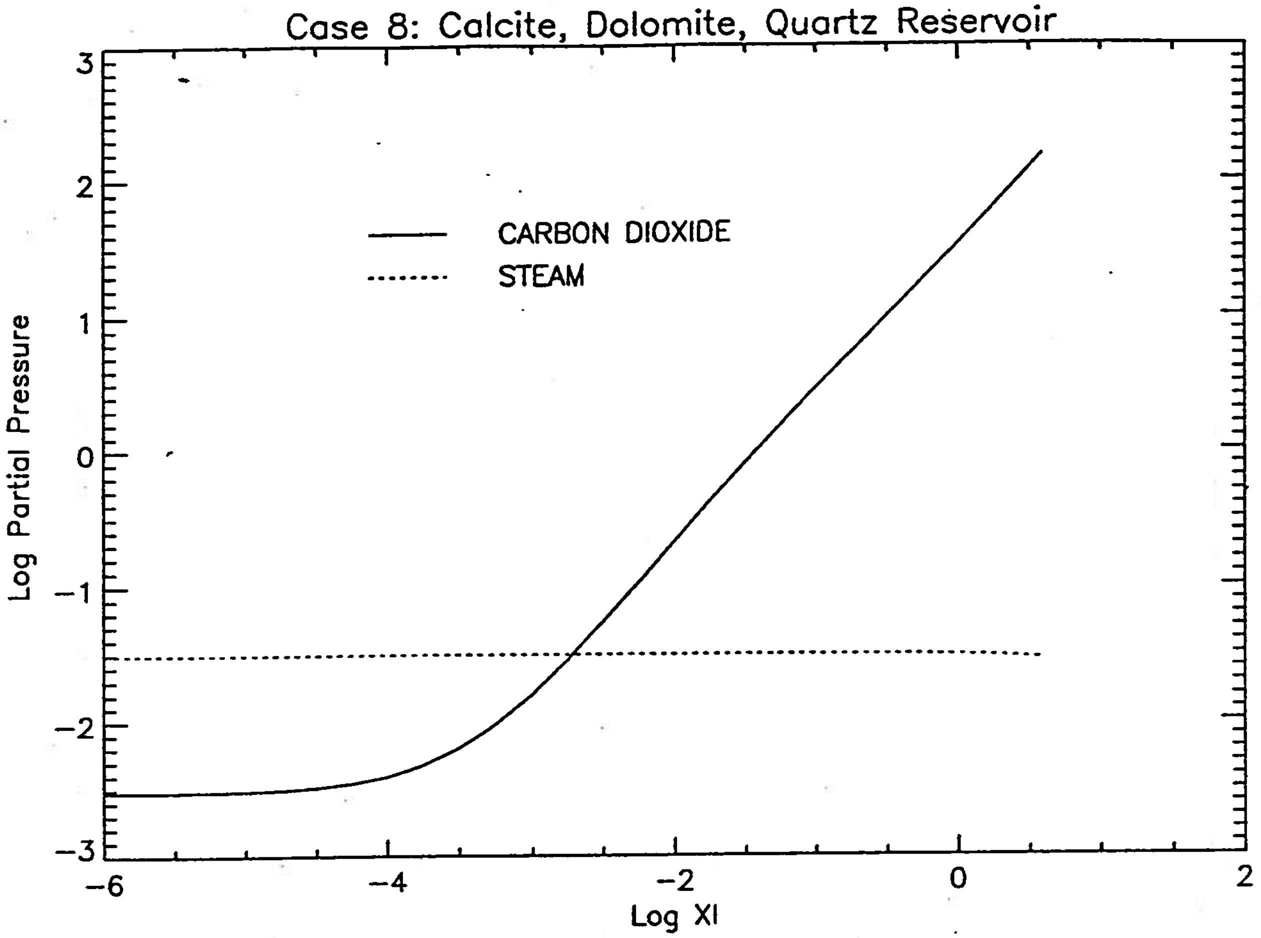


Figure 11.5.4a

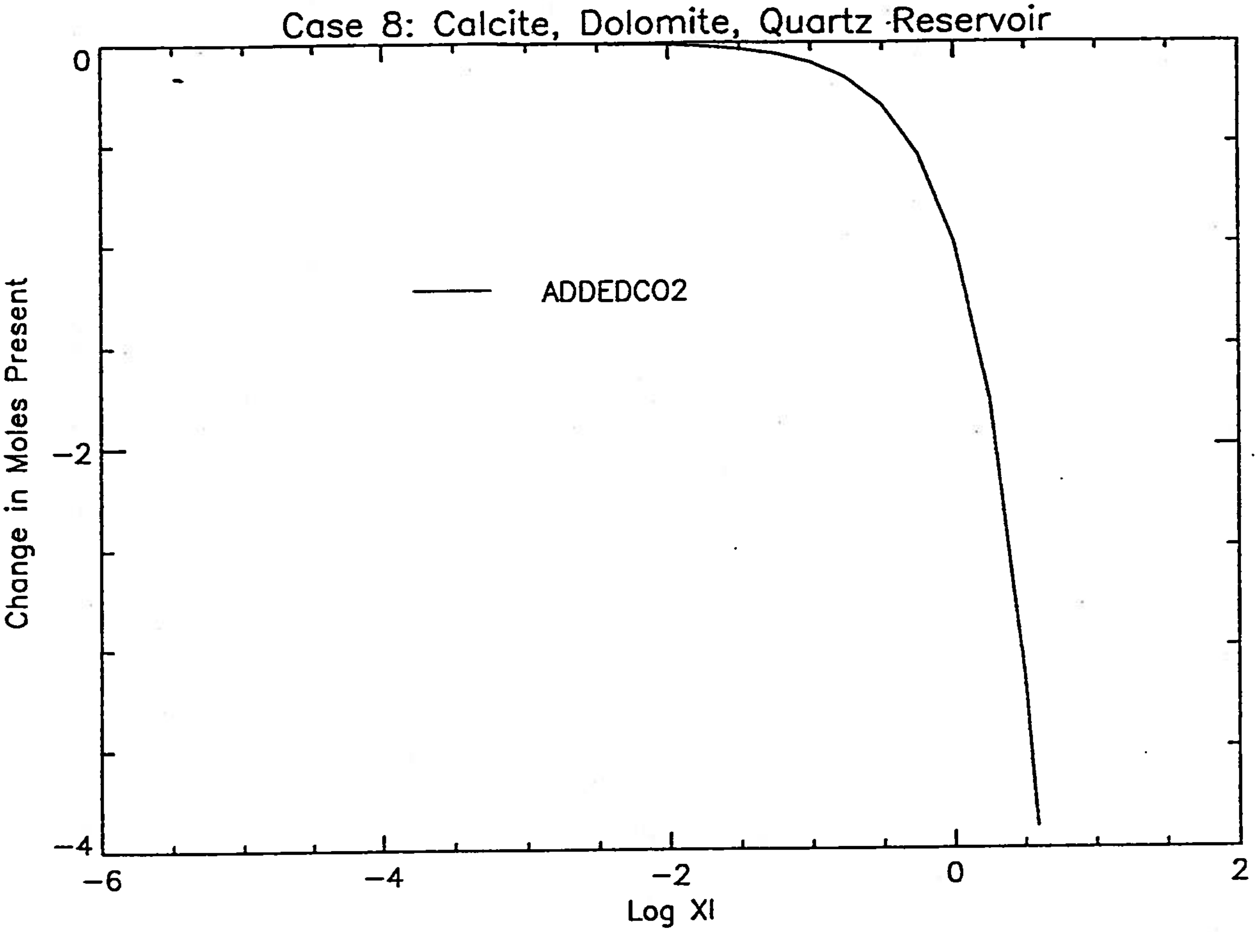


Figure 11.5.4b1

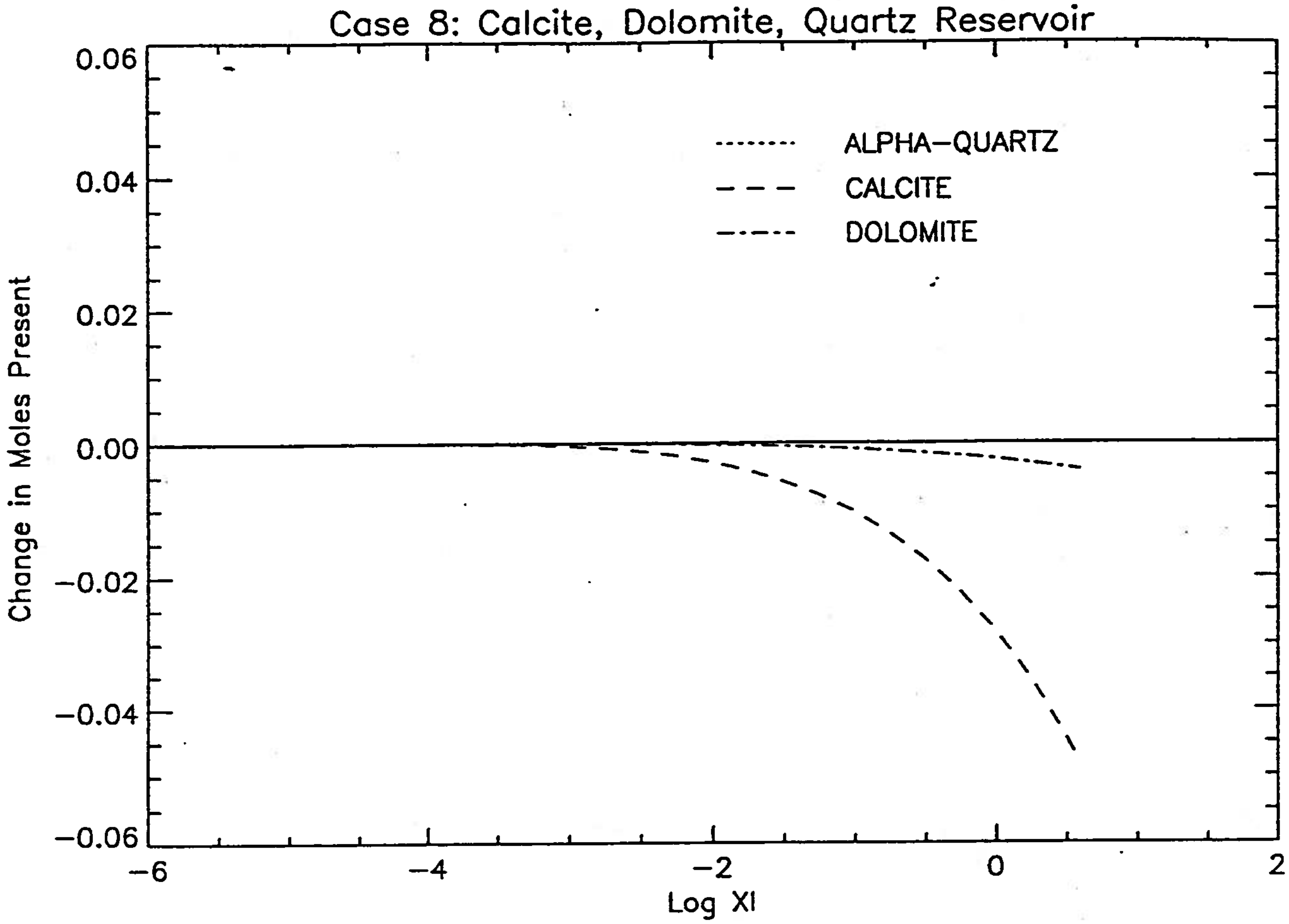


Figure 11.5.4b2

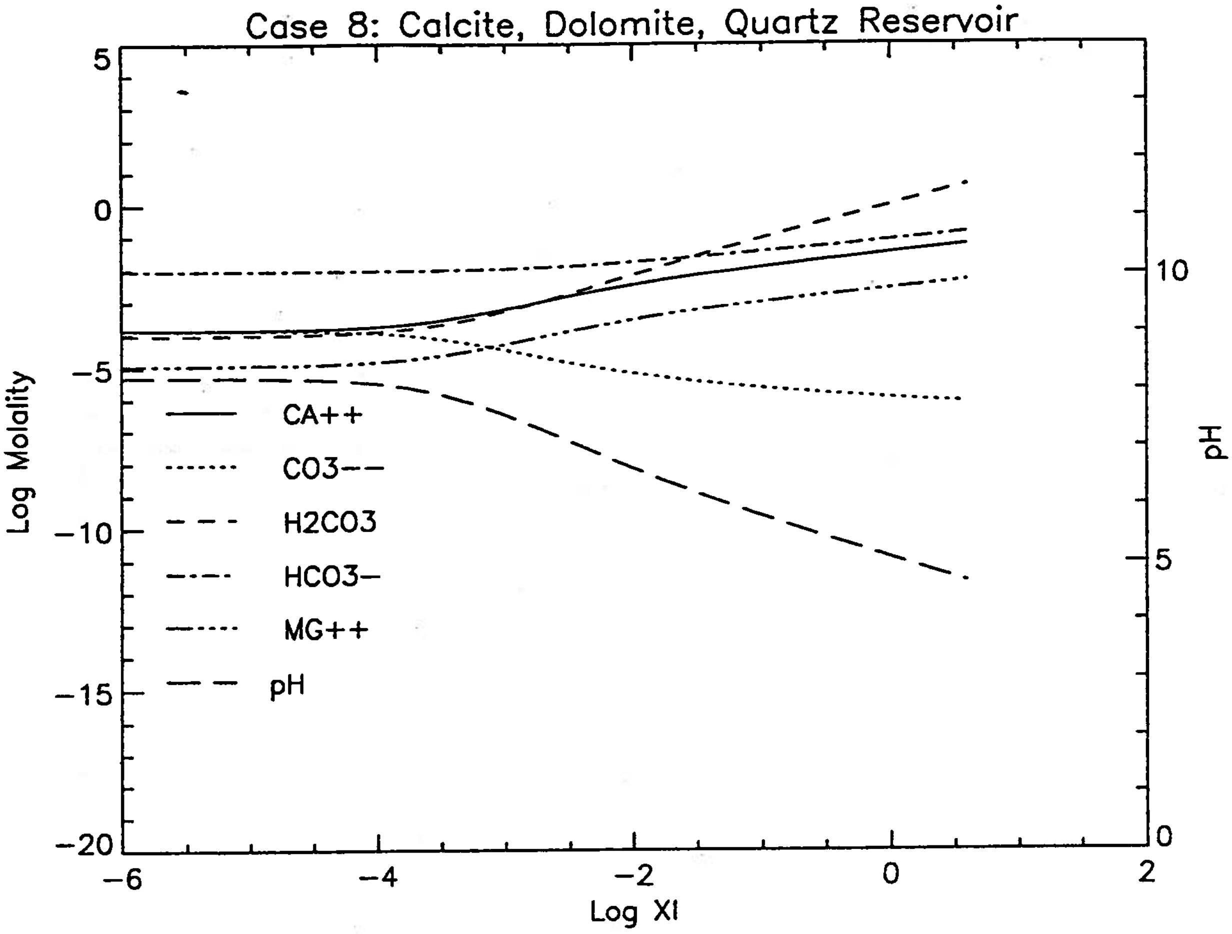


Figure 11.5.4c

Figure 11.5.5

Reaction of a Formation Water Brine with a calcite-dolomite limestone aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

a: Buildup of the partial pressure of CO_2 in bars.

b1: Molar amount of CO_2 injected into the aquifer.

b2: Change in the moles of mineral reactants.

c: Change in the molality of the aqueous species.

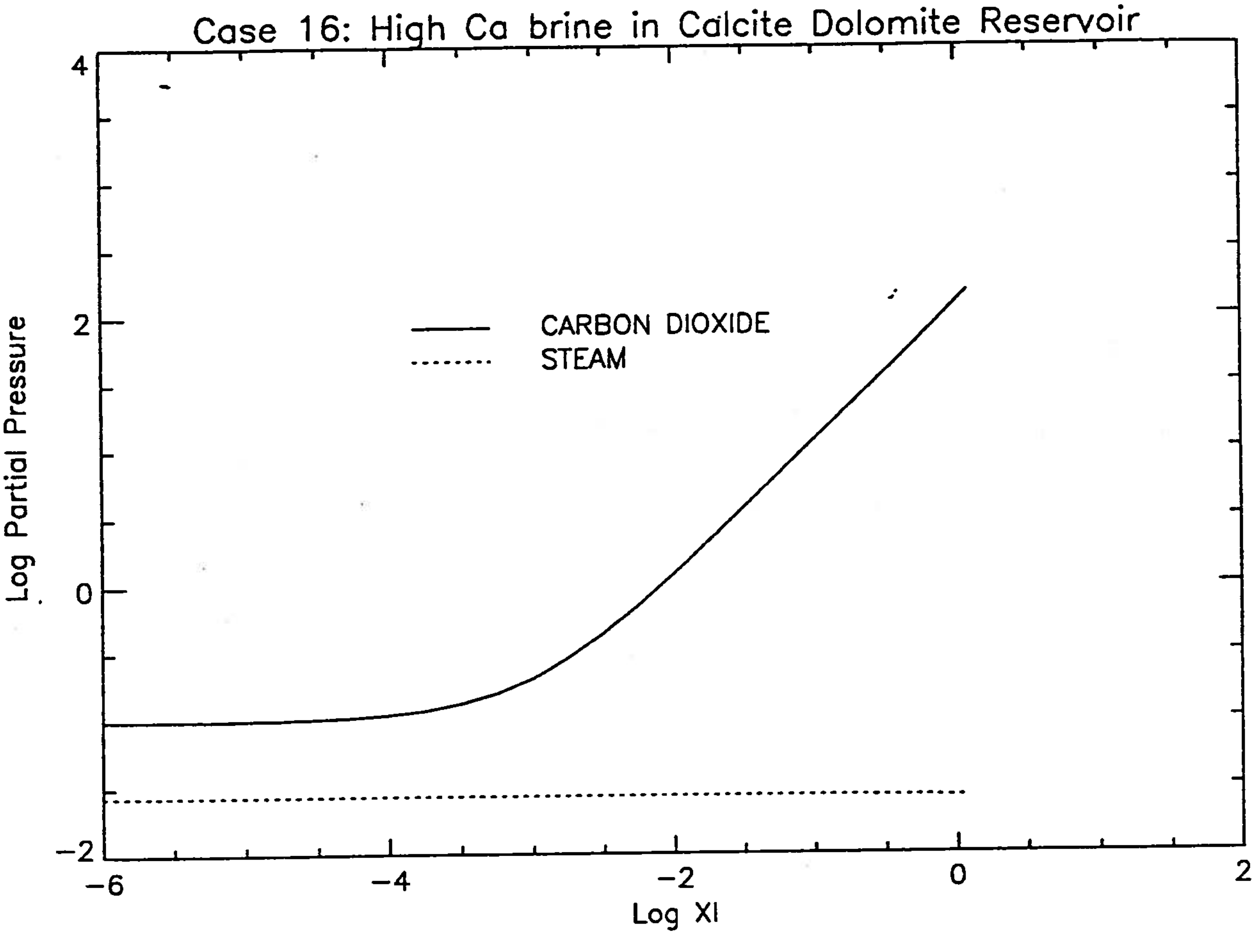


Figure 11.5.5a

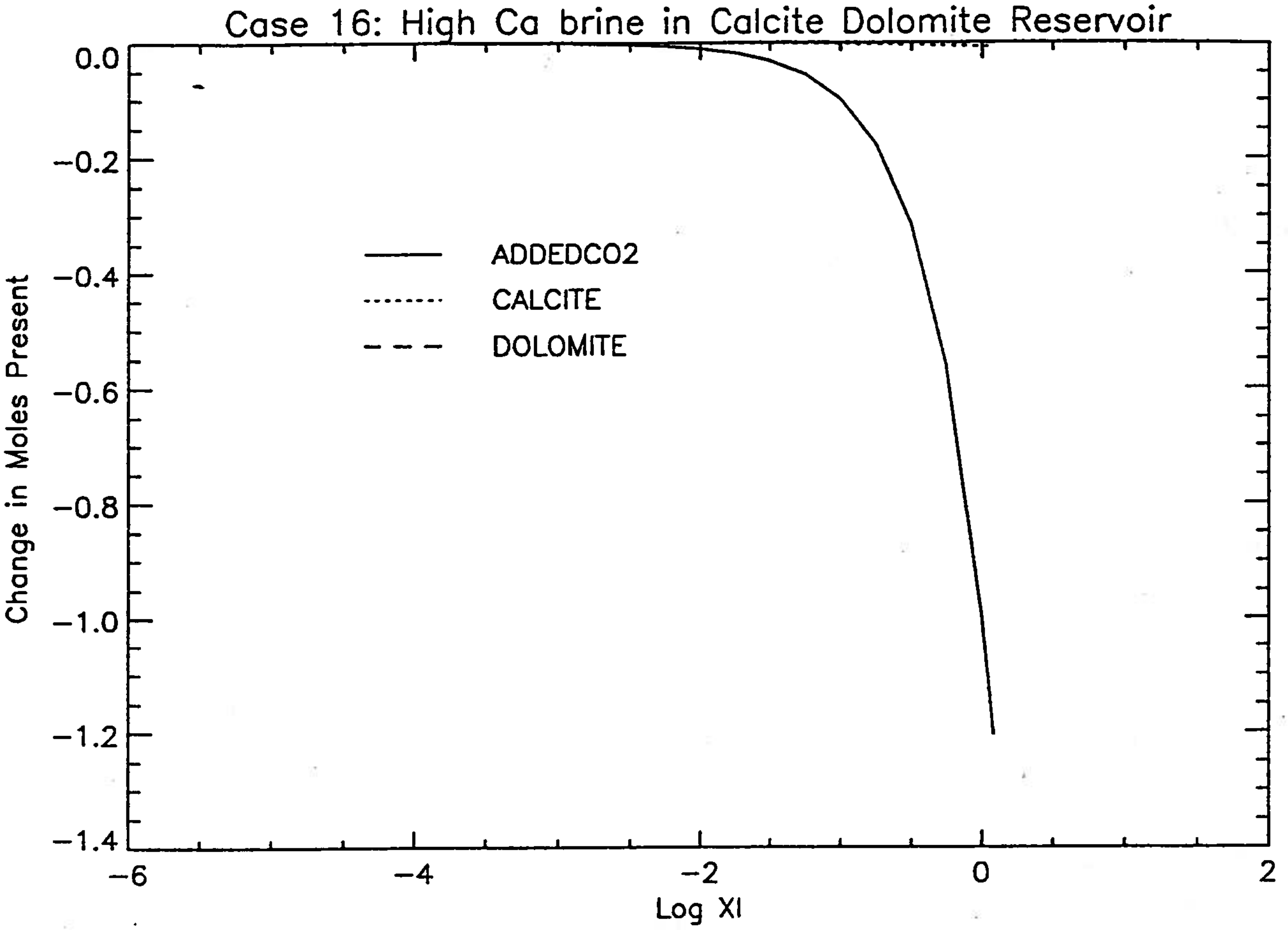
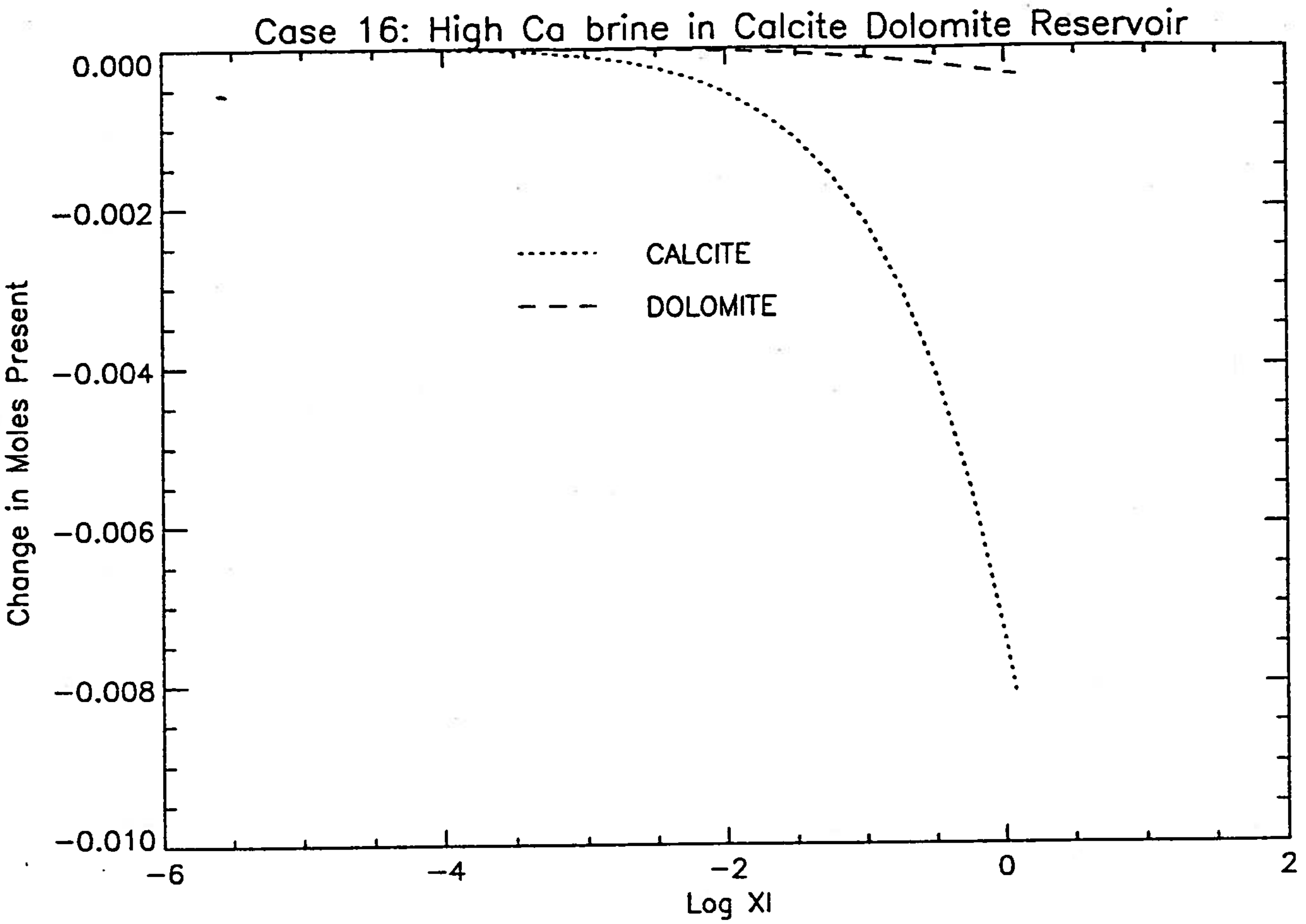


Figure 11.5.5b1



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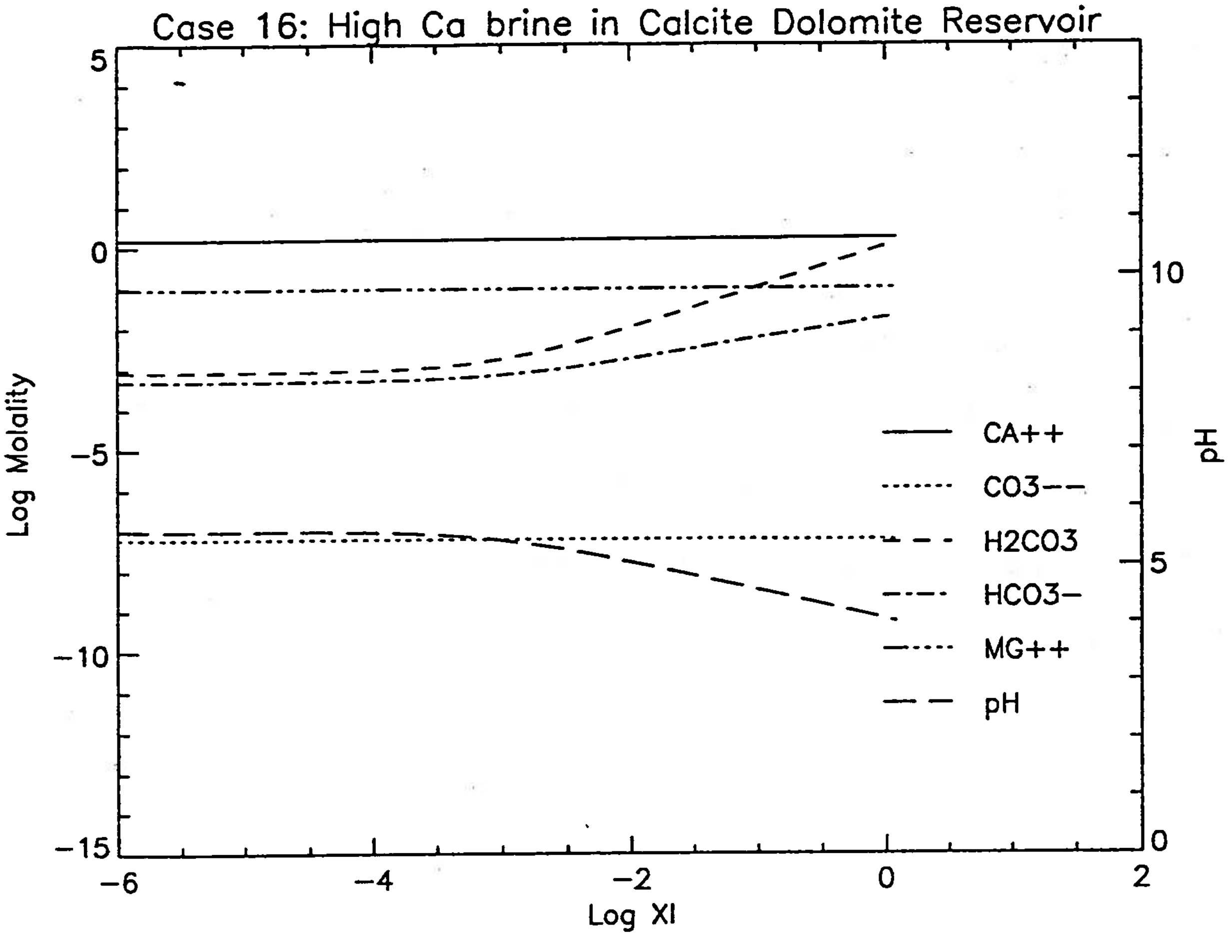


Figure 11.5.5c

Figure 11.5.6

Reaction of Brackish Formation Water with a calcite-dolomite-clay exchanger limestone aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

a: Buildup of the partial pressure of CO_2 in bars.

b1: Molar amount of CO_2 injected into the aquifer.

b2: Change in the moles of mineral reactants.

c1: Change in the molality of the aqueous species.

c2: Change in the composition of the clay exchanger.

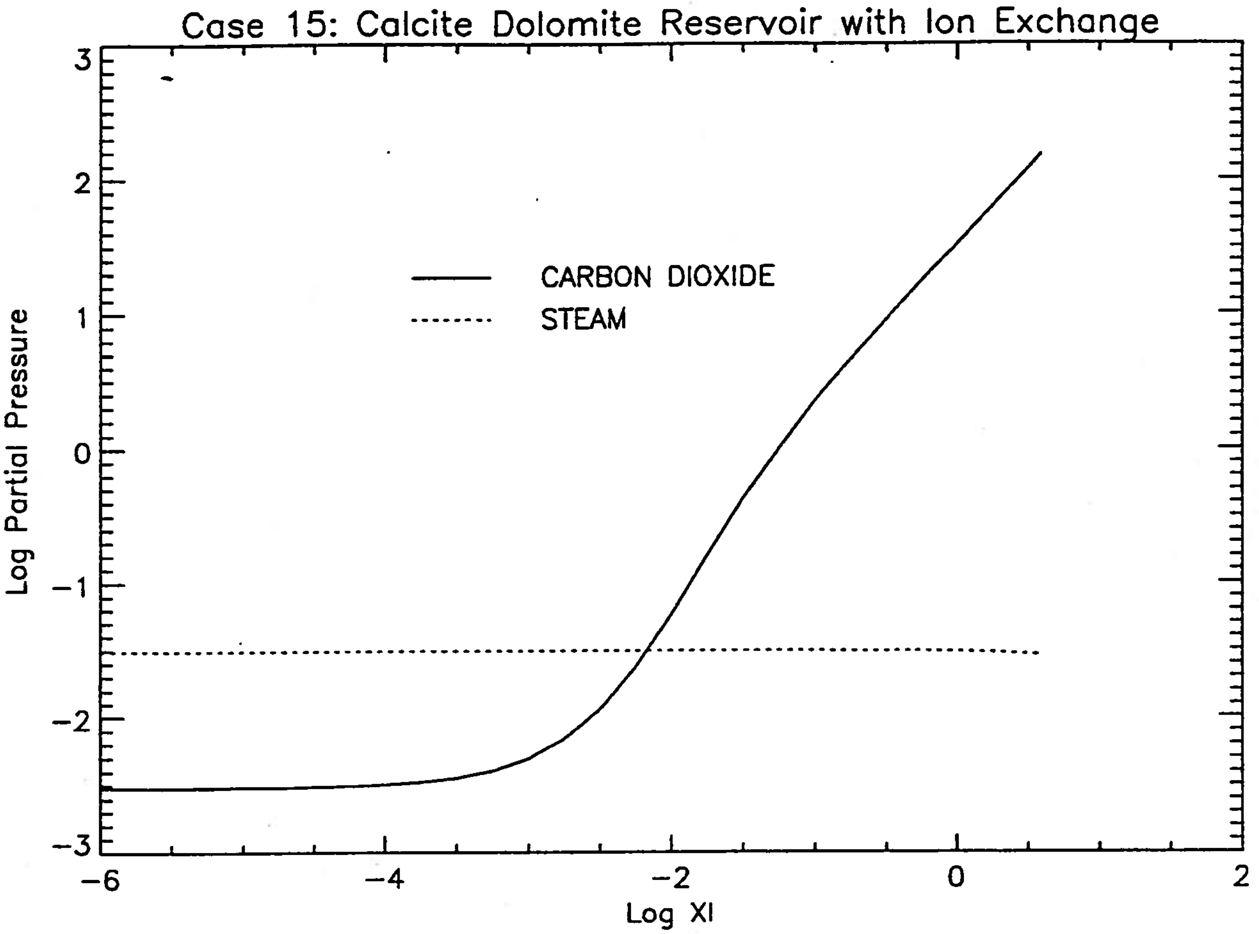


Figure 11.5.6a

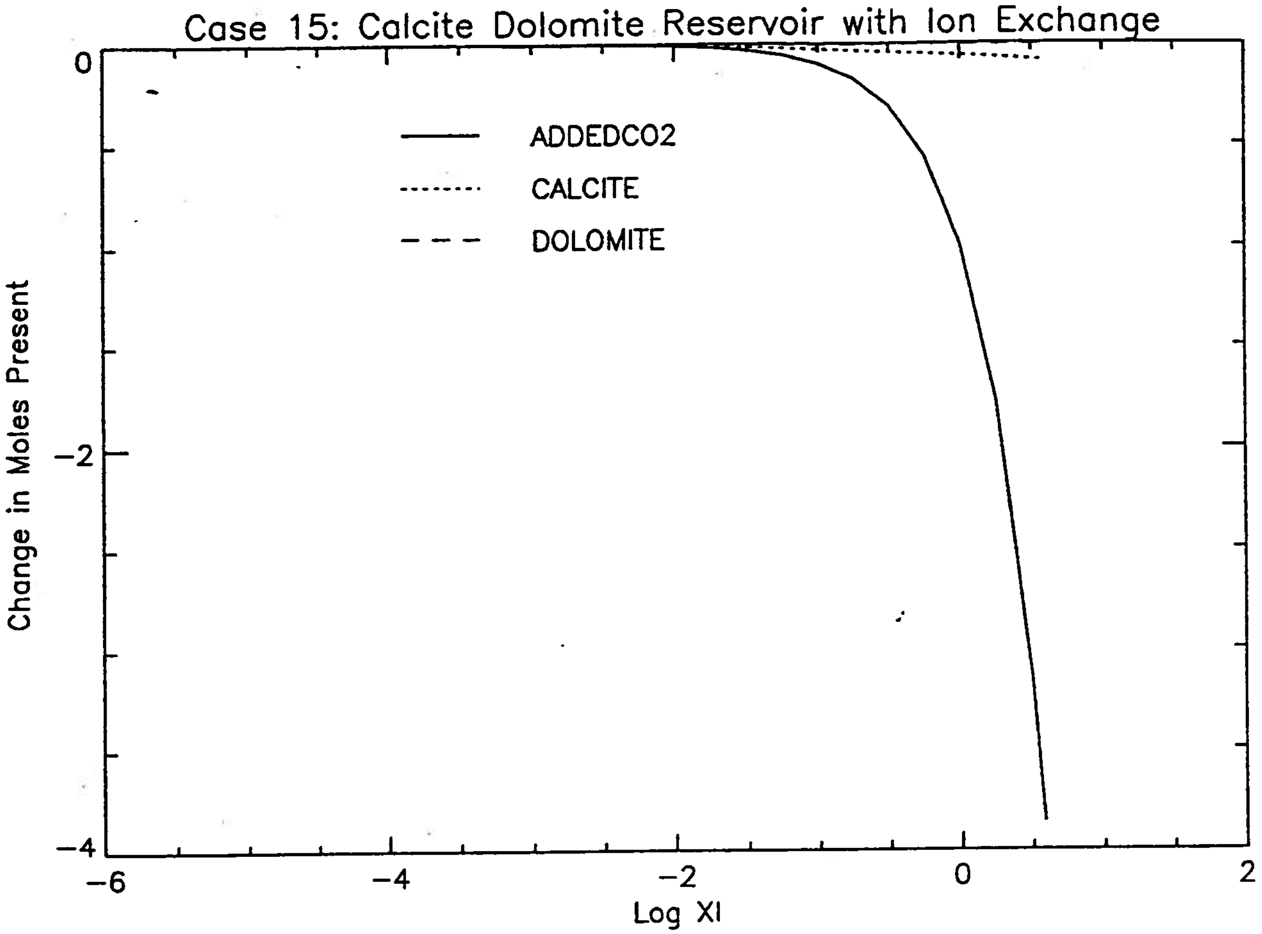


Figure 11.5.6b1

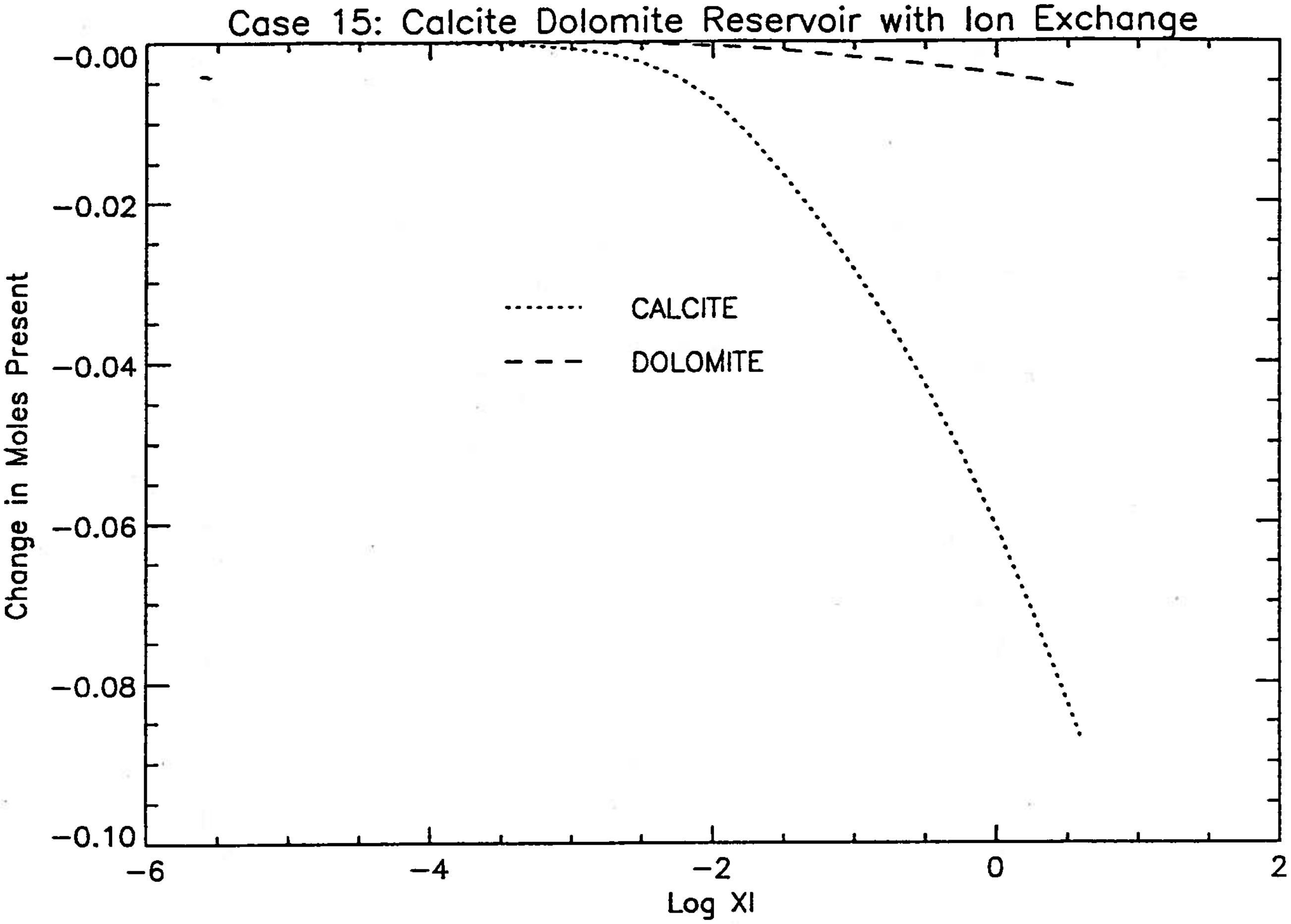


Figure 11.5.6b2

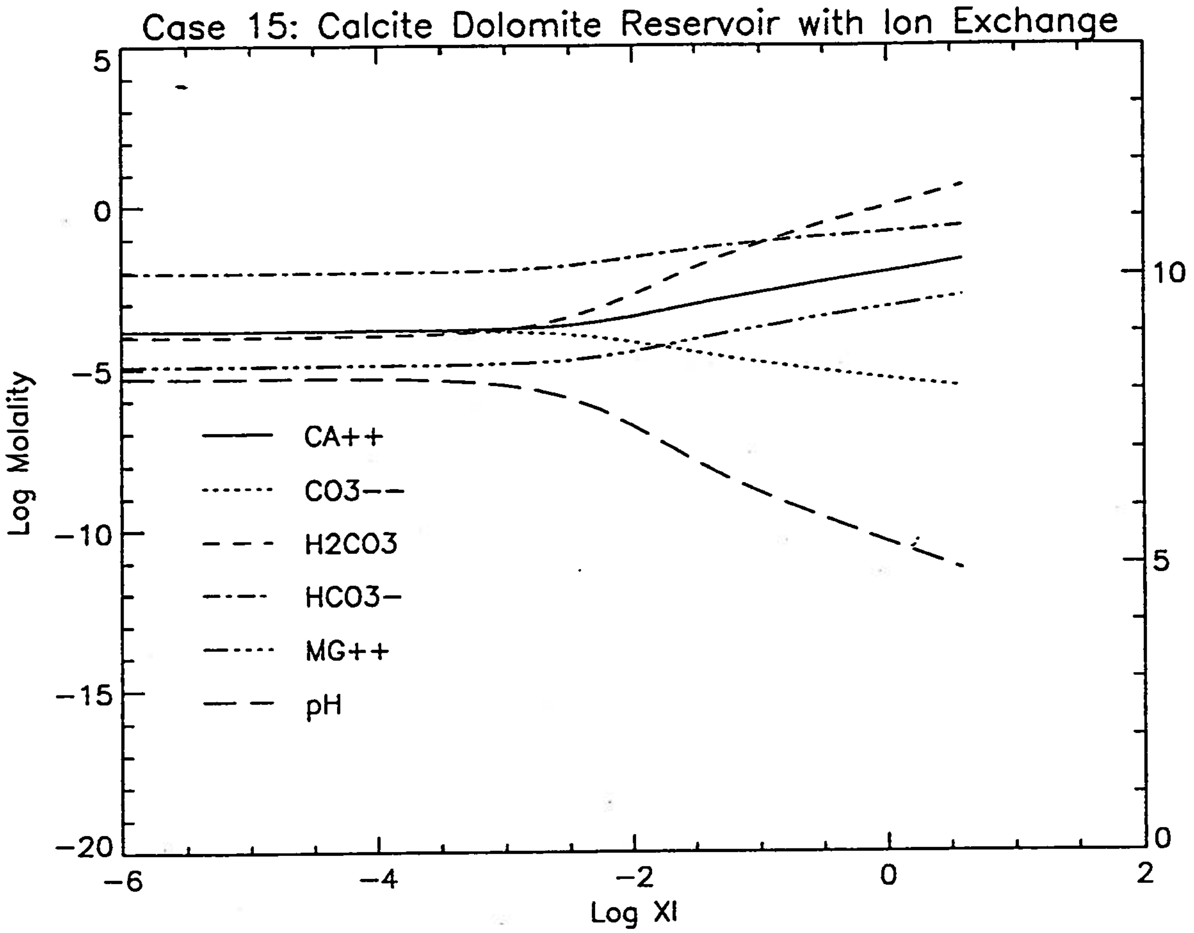


Figure 11.6c1

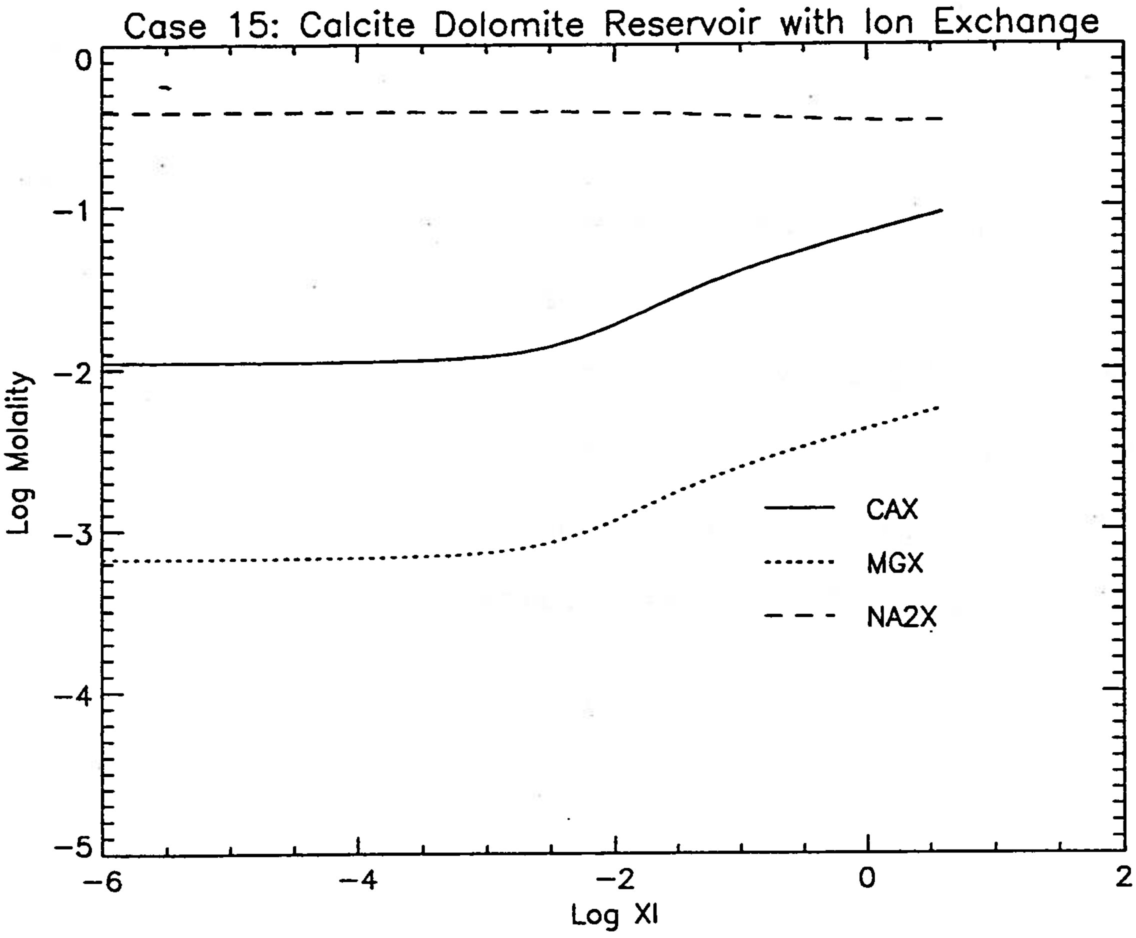


Figure 11.5.6c2

Figure 11.5.7

Reaction of Formation Water Brine with a calcite-dolomite-clay exchanger limestone aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

a: Buildup of the partial pressure of CO_2 in bars.

b1: Molar amount of CO_2 injected into the aquifer.

b2: Change in the moles of mineral reactants.

c1: Change in the molality of the aqueous species.

c2: Change in the composition of the clay exchanger.

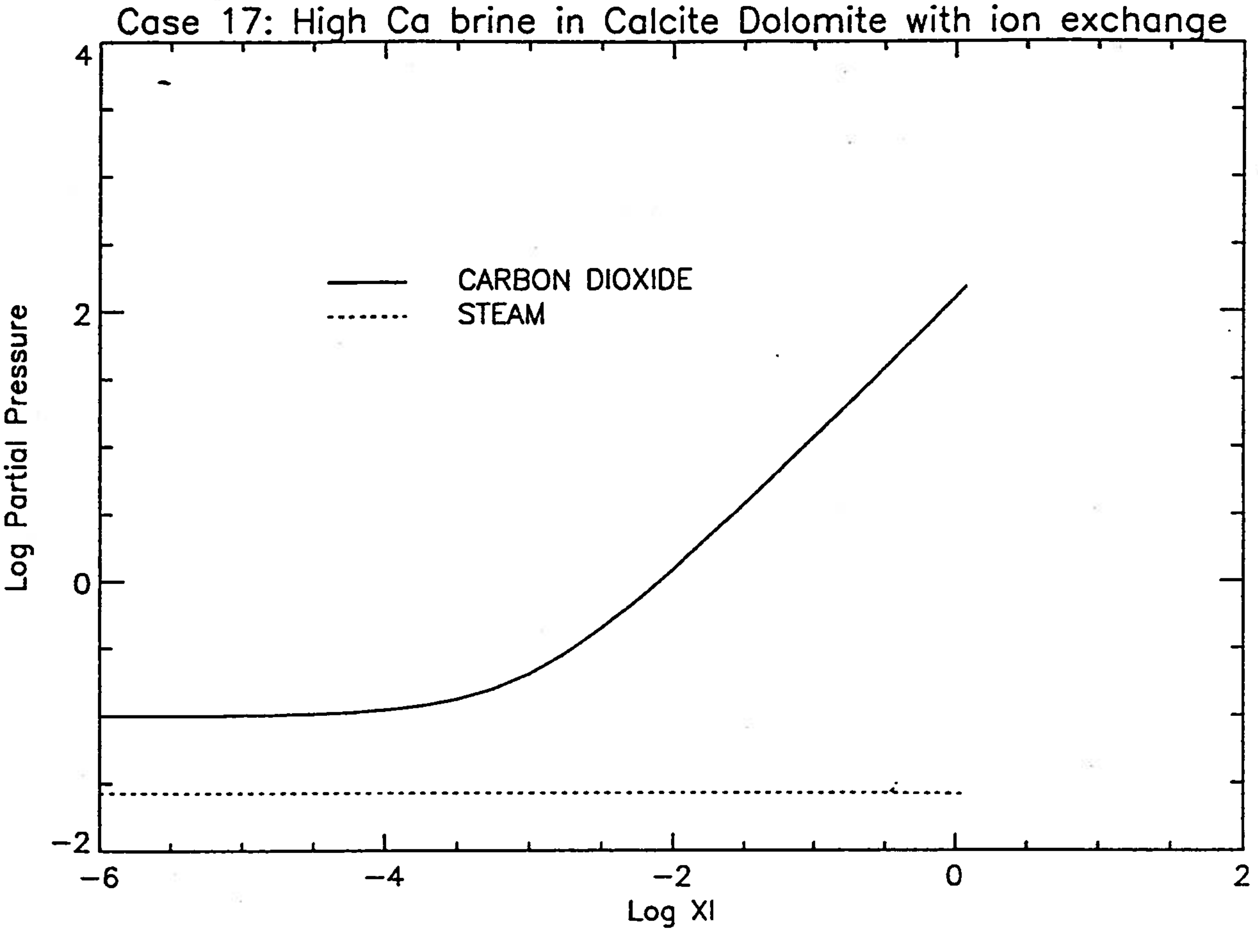
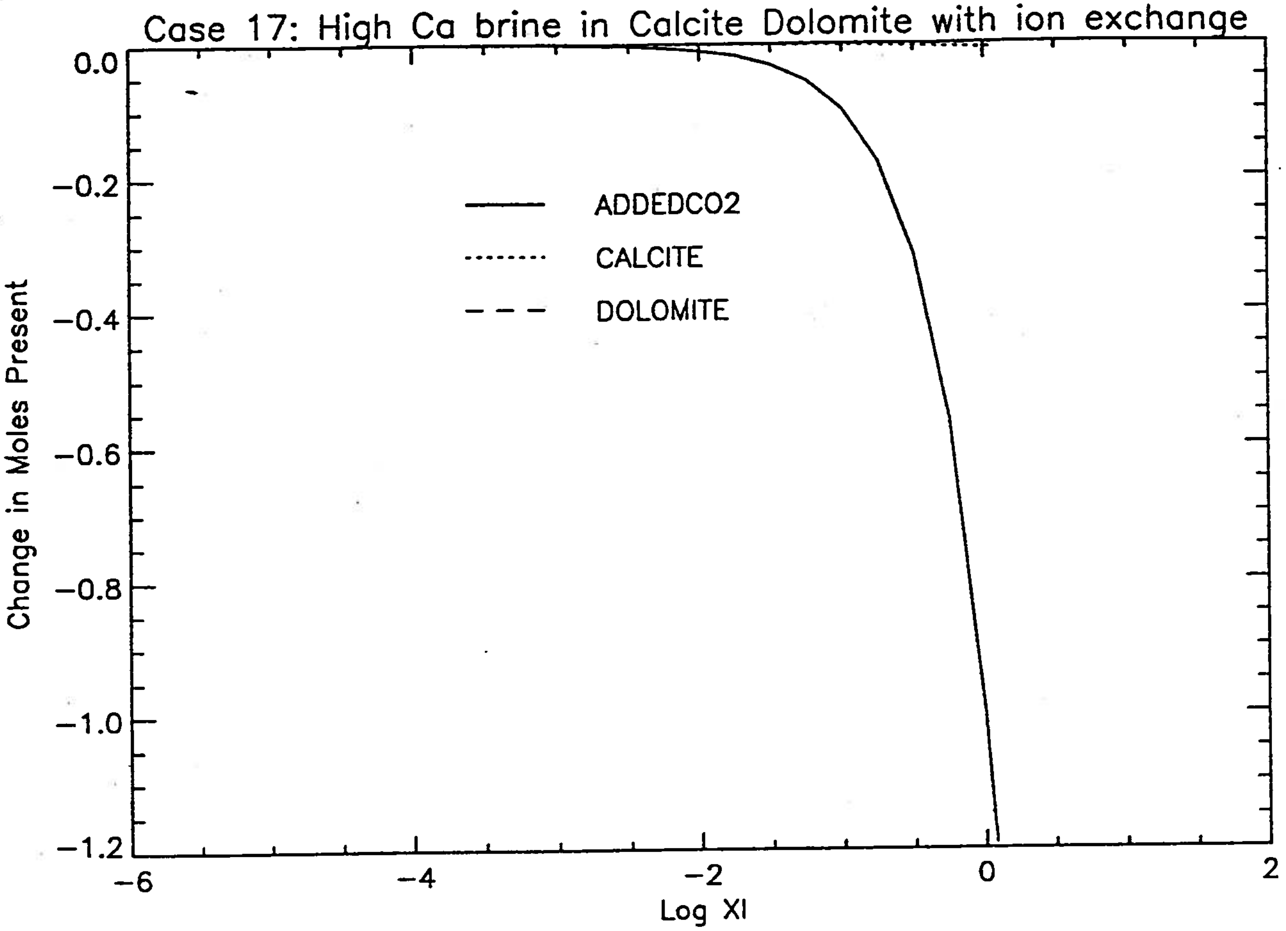


Figure 11.5.7a



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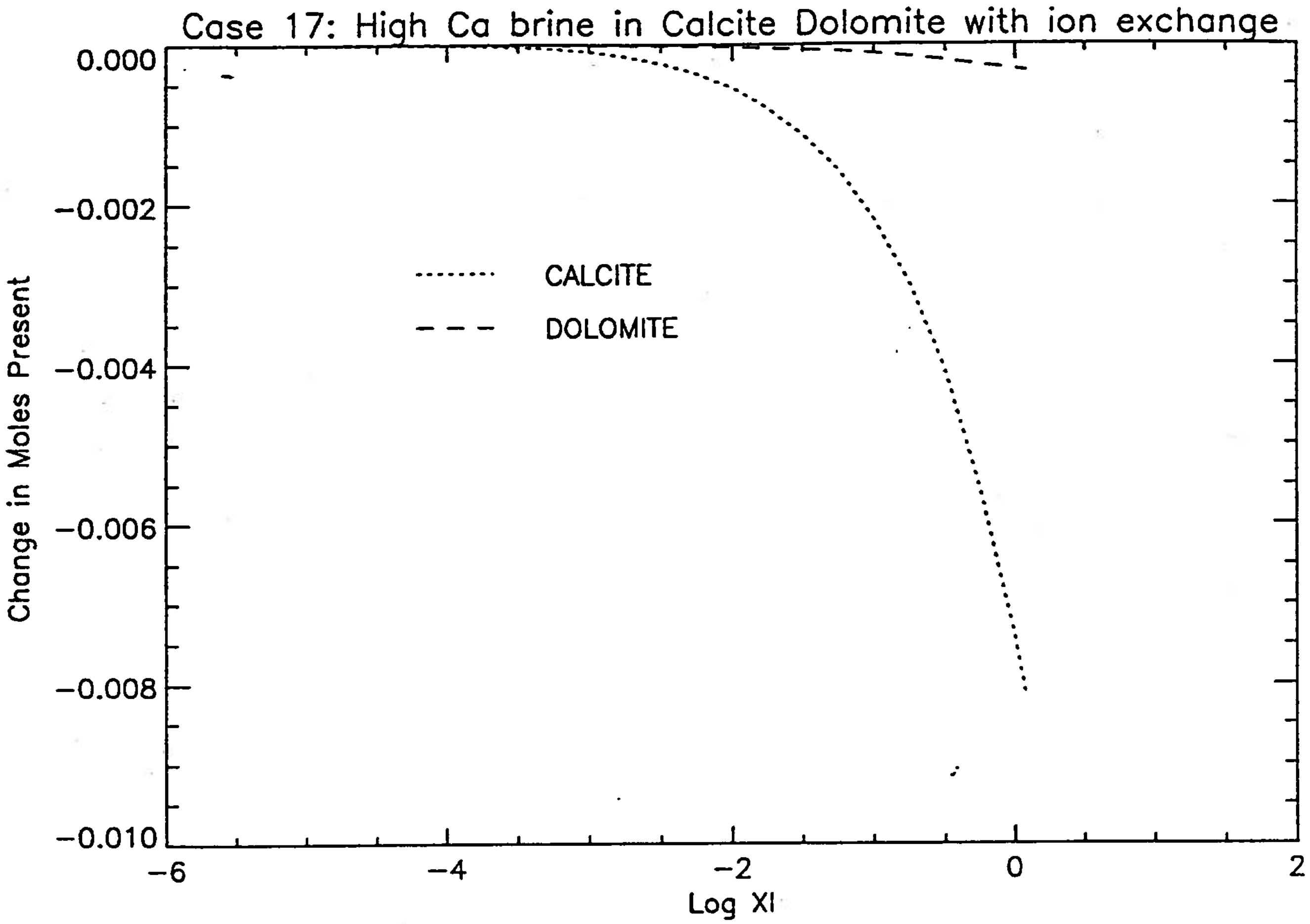

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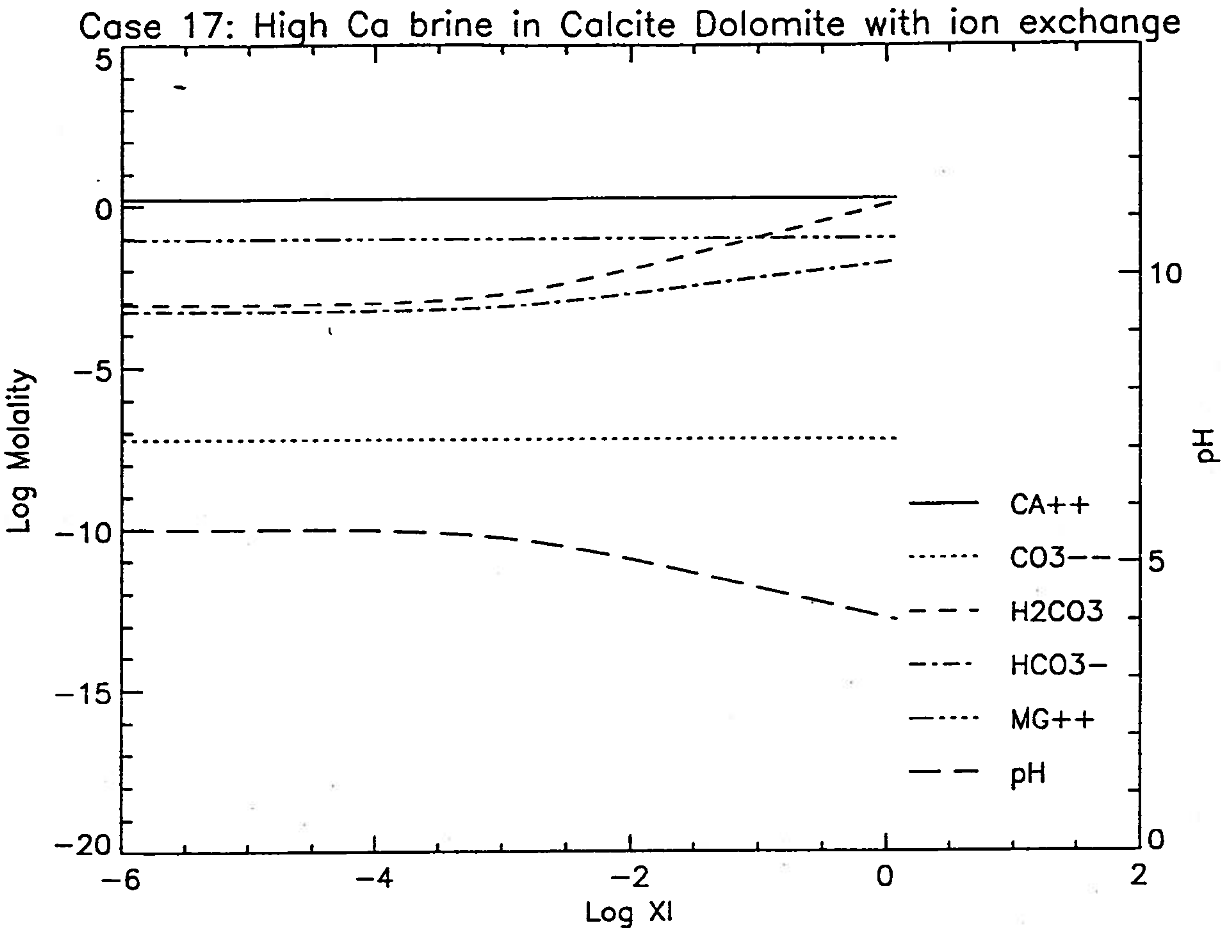

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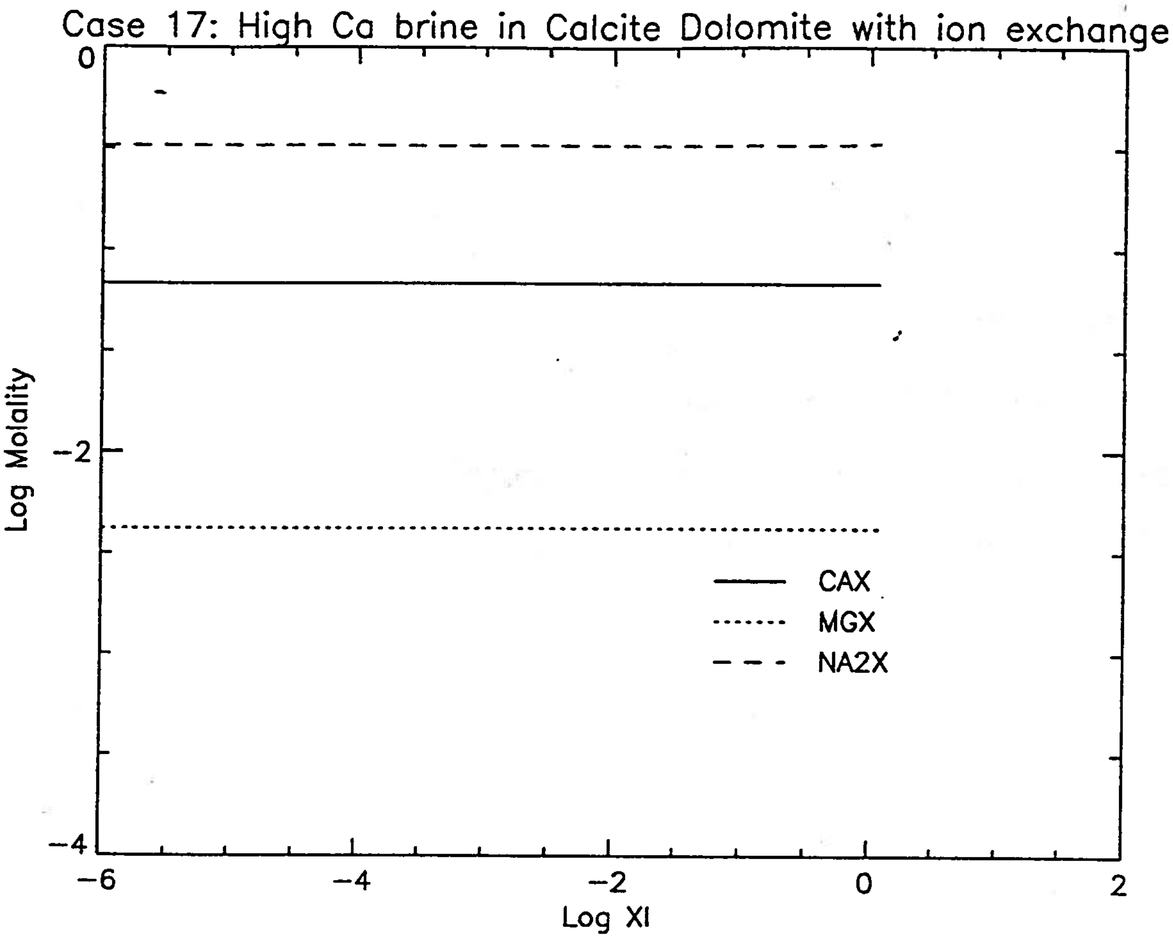


Figure 11.5.7c2

Figure 11.5.8

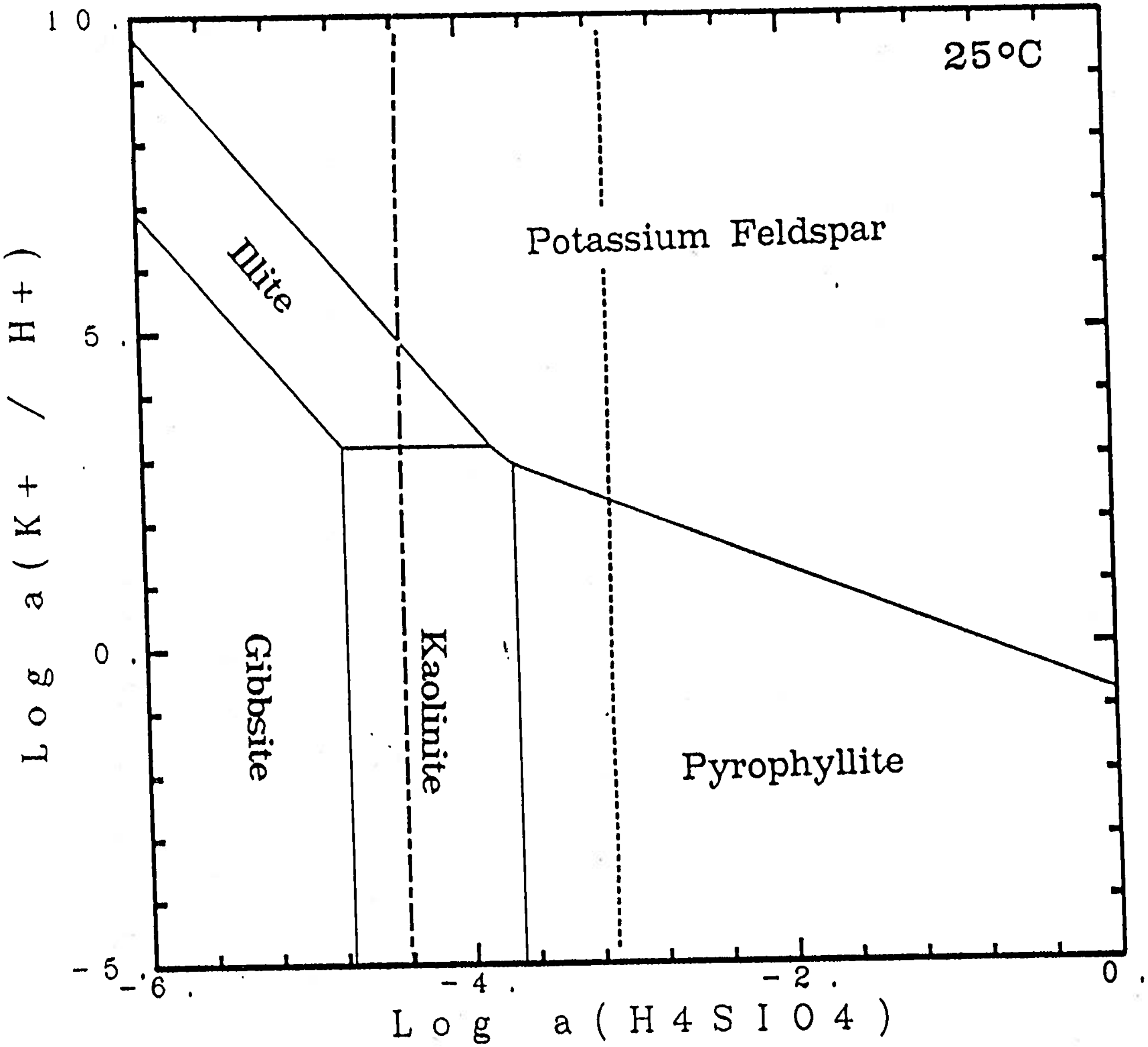
Mineral Stability Fields in Aqueous Fluids plotted as a function of the thermodynamic concenttrations or activities of the aqueous species in water.

a: Activity ratio of (K^+/H^+) versus activity of (H_4SiO_4)

b: Activity ratio of (Na^+/H^+) versus activity of (H_4SiO_4)

c: Activity ratio of ($Ca^+/(H^+)^2$) versus activity of (H_4SiO_4)

d: Activity ratio of ($Mg^+/(H^+)^2$) versus activity of (H_4SiO_4)



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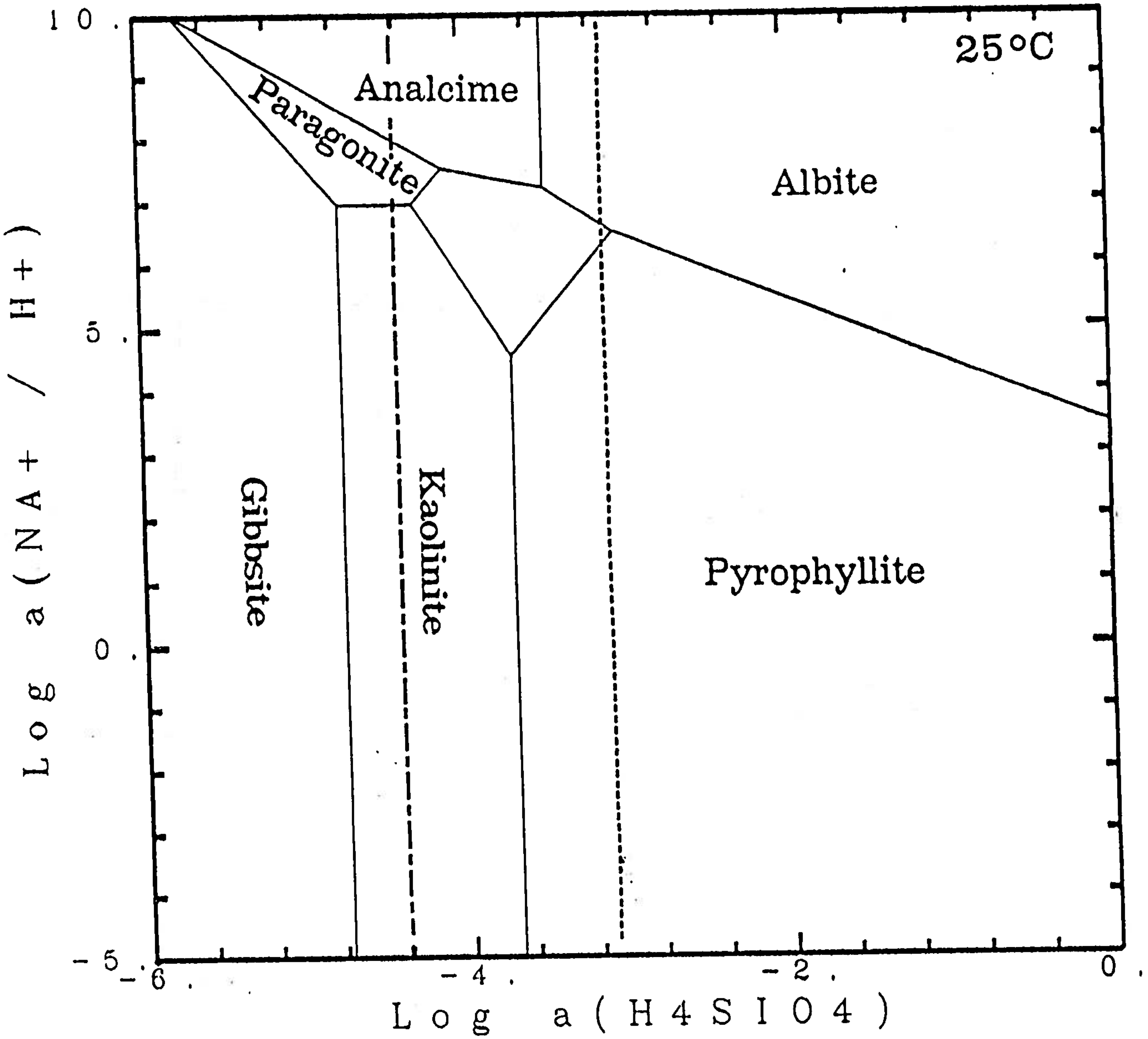

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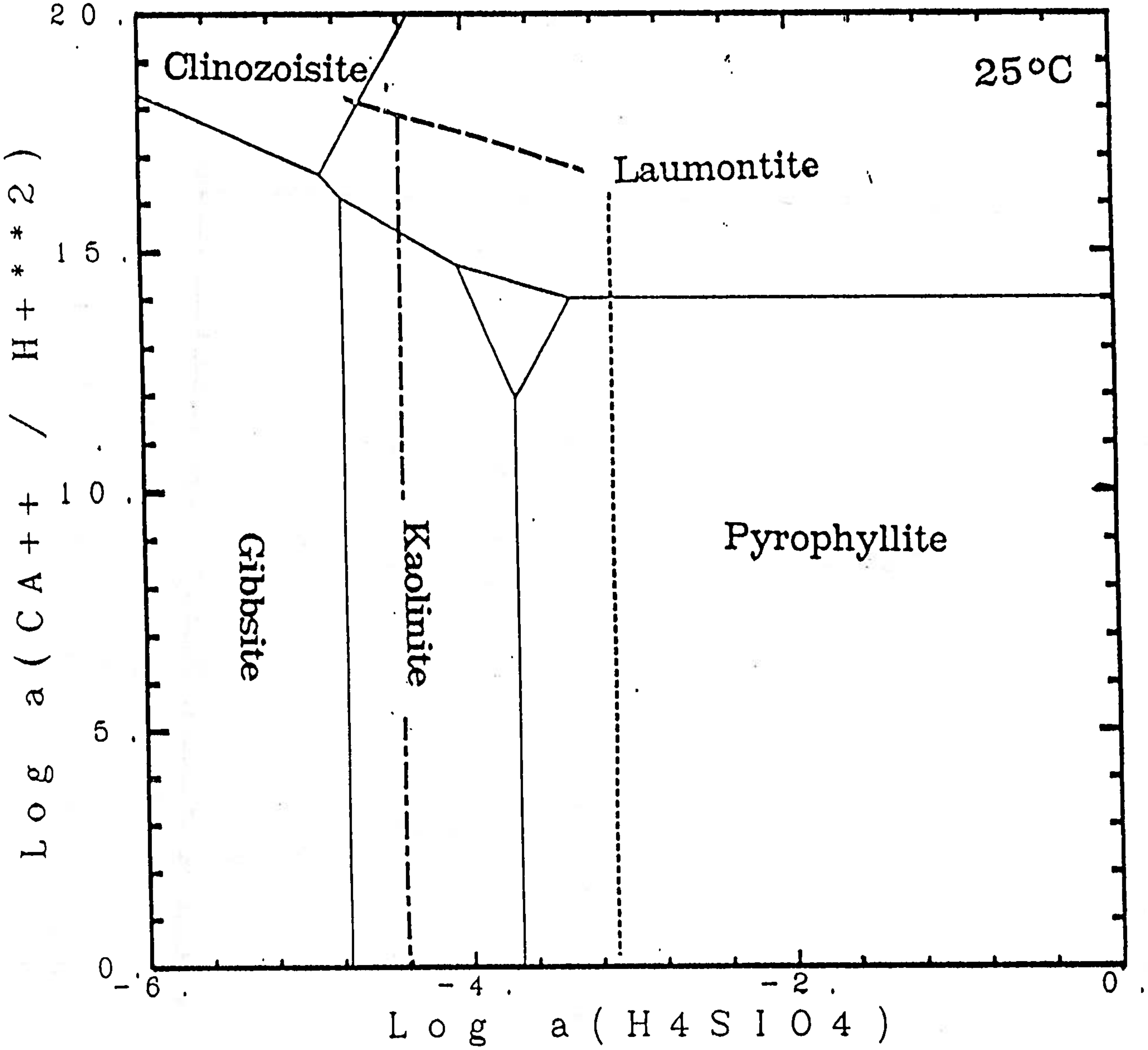


Figure 11.5.8c

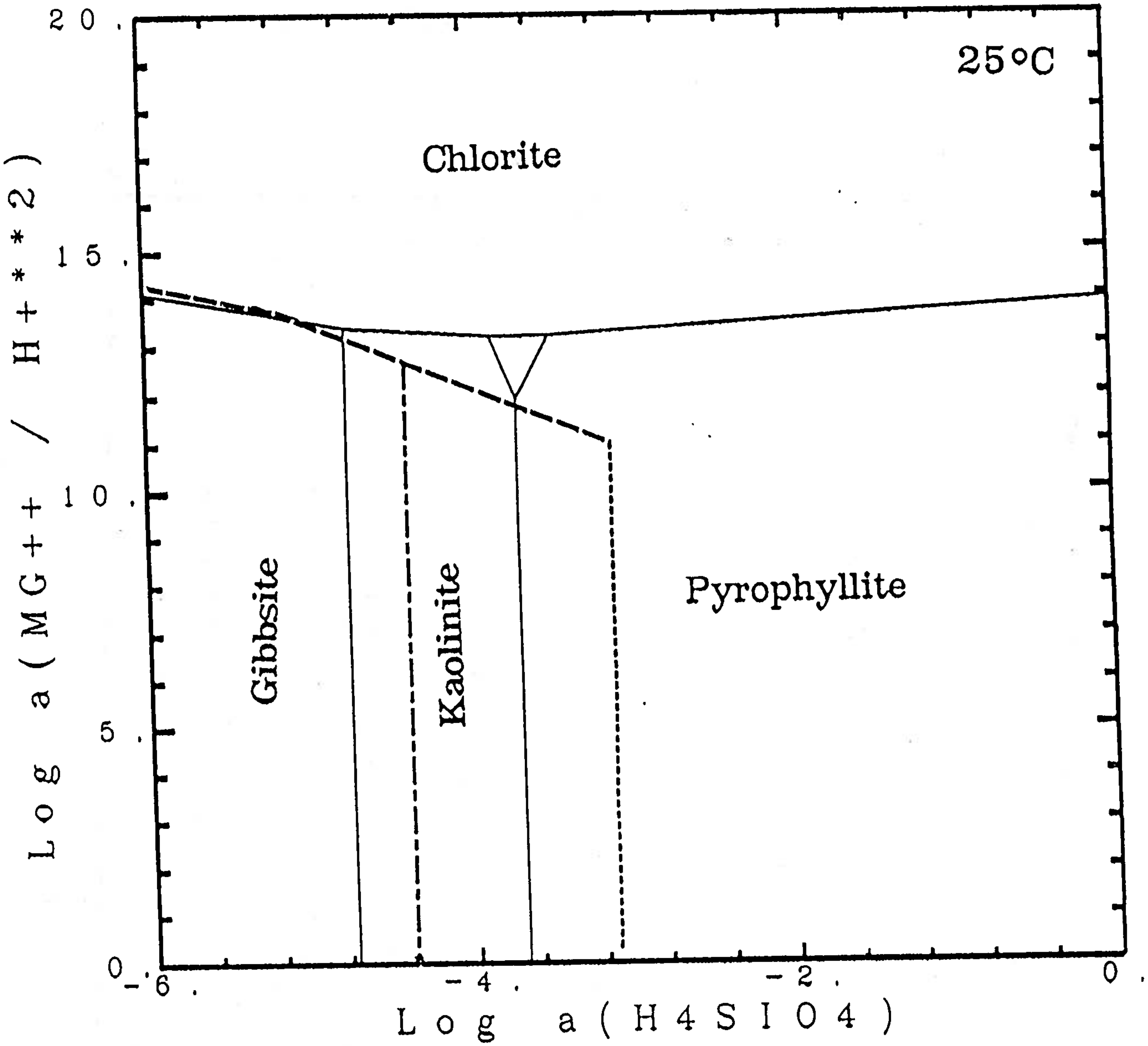


Figure 11.5.8d

Figure 11.5.9

Reaction of a Brackish Formation Water with an anorthite-quartz-illite siliciclastic aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

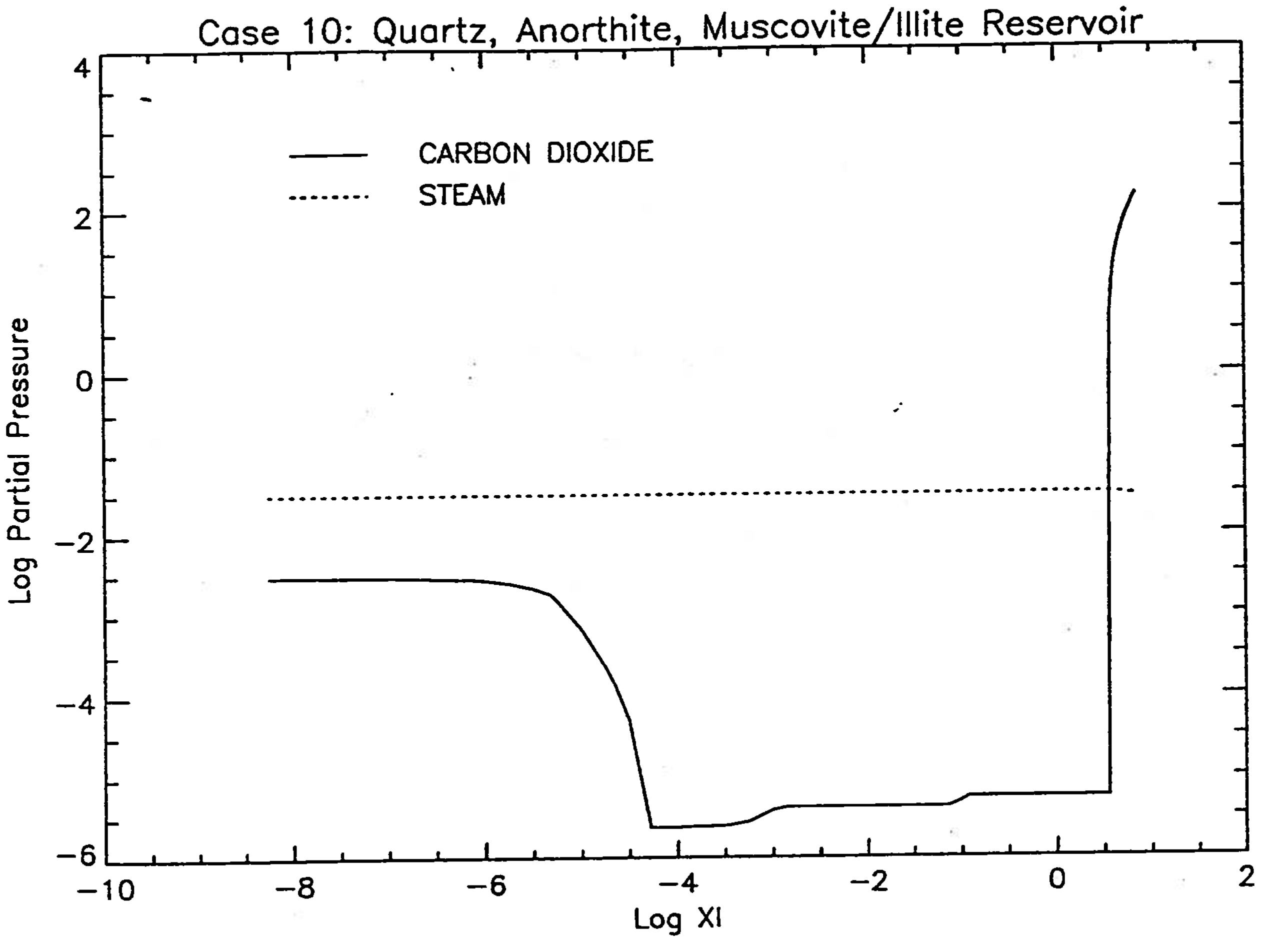
a: Buildup of the partial pressure of CO_2 in bars.

b1: Molar amount of CO_2 injected into the aquifer.

b2: Change in the moles of mineral reactants.

b3: Change in the moles of mineral products.

c: Change in the molality of the aqueous species.



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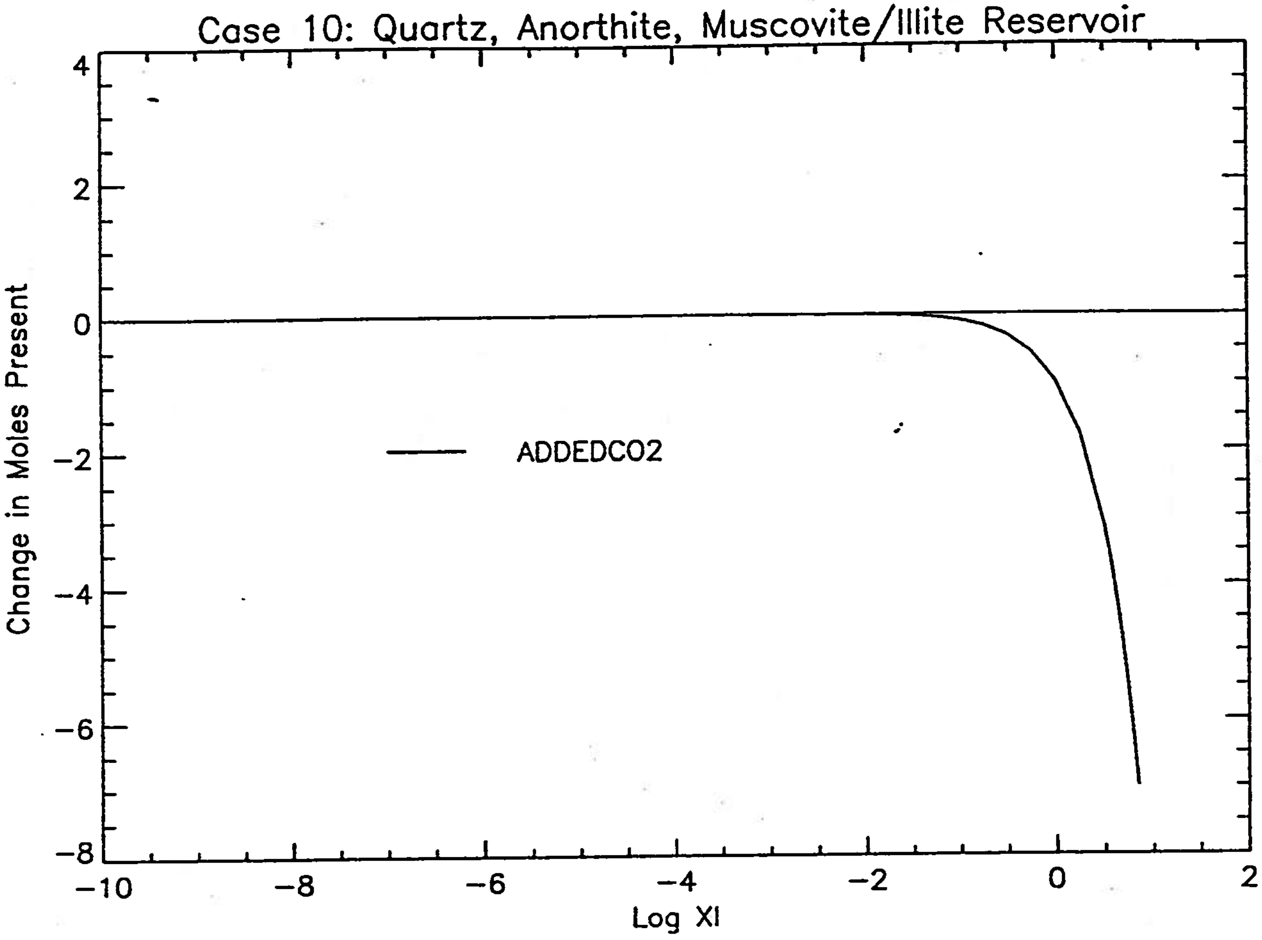

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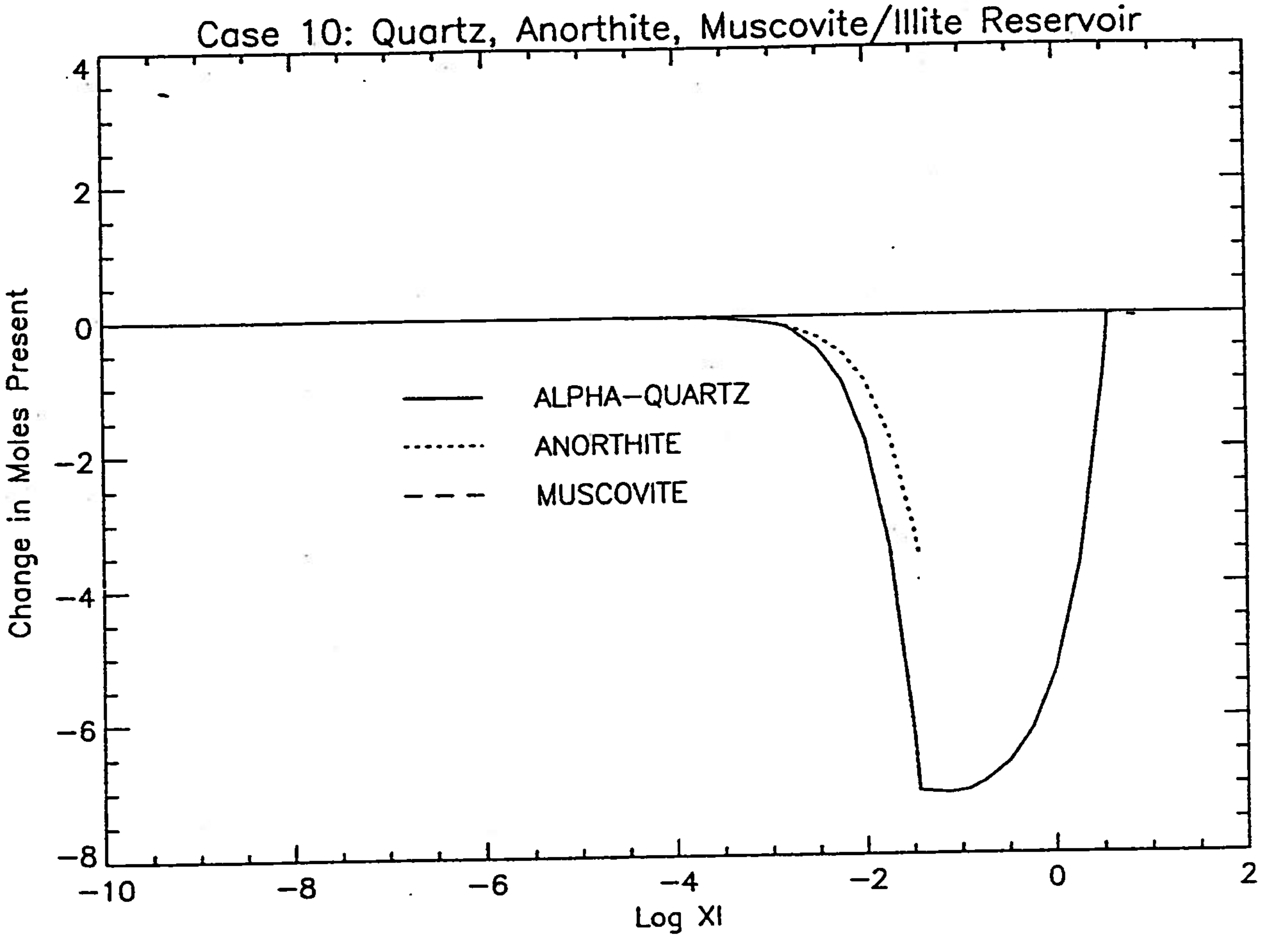

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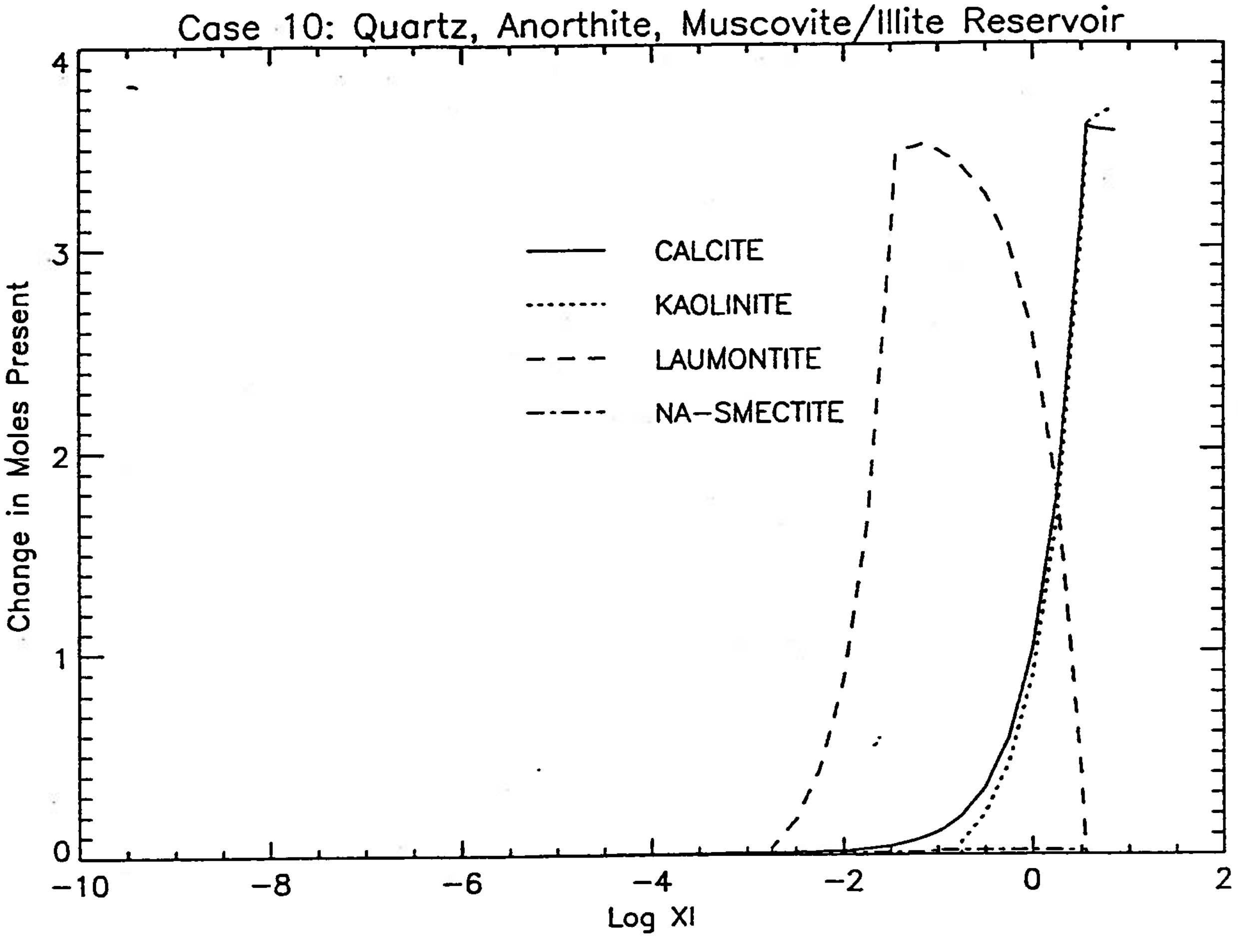

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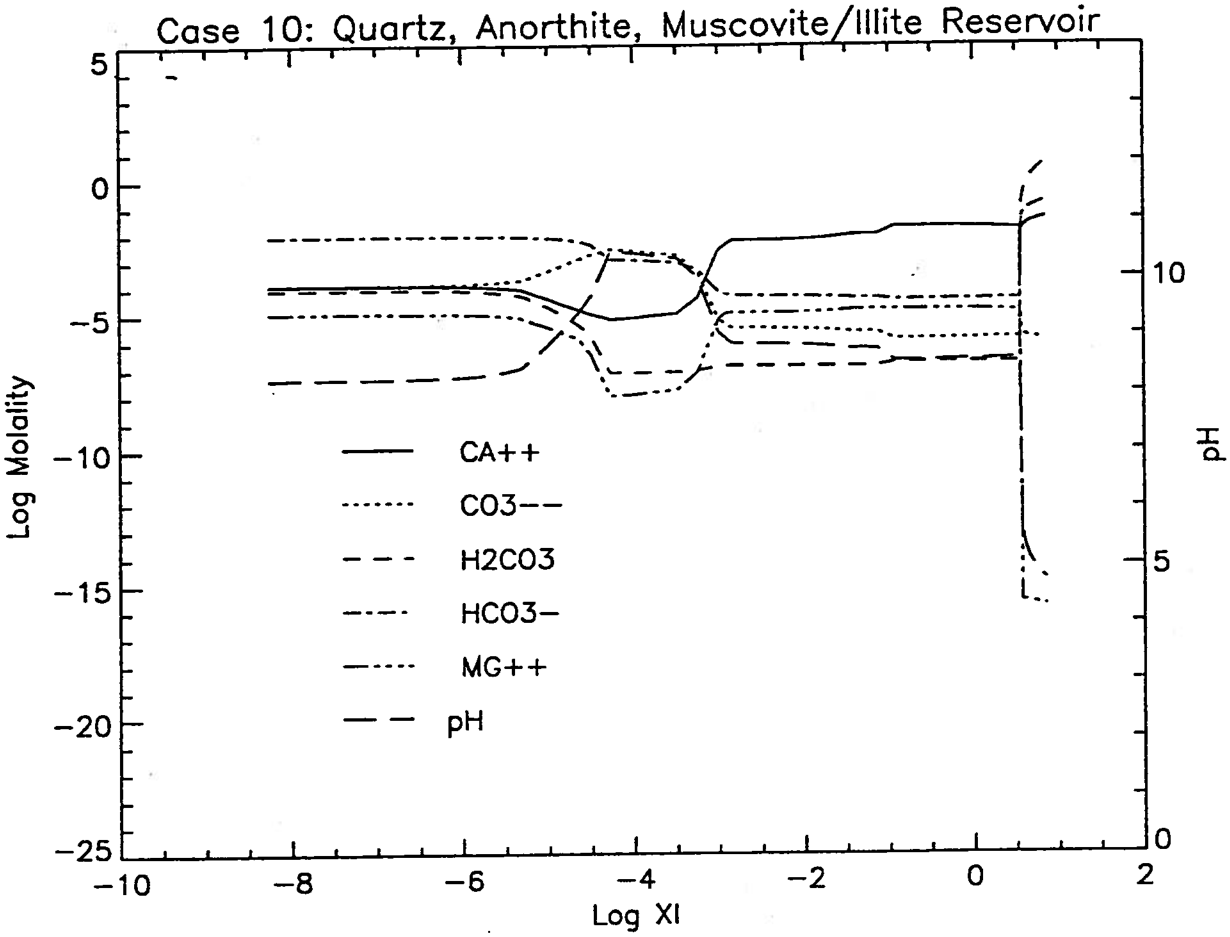


Figure 11.5.9c

Figure 11.5.10

Reaction of a Formation Water Brine with an anorthite-quartz siliciclastic aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

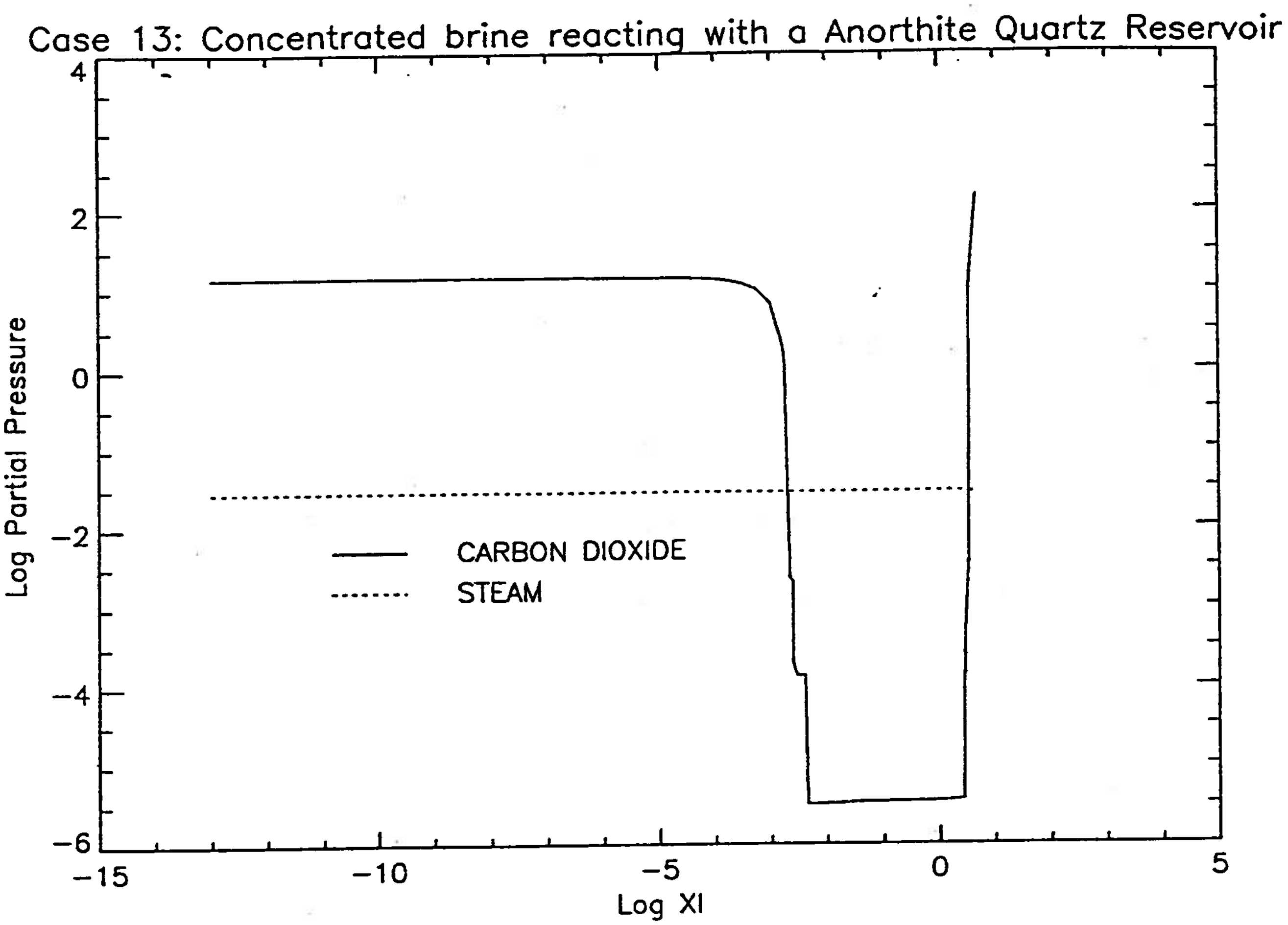
a: Buildup of the partial pressure of CO_2 in bars.

b1: Molar amount of CO_2 injected into the aquifer & change in the moles of mineral reactants.

b2: Change in the moles of mineral products.

b3: Change in the moles of mineral products.

c: Change in the molality of the aqueous species.



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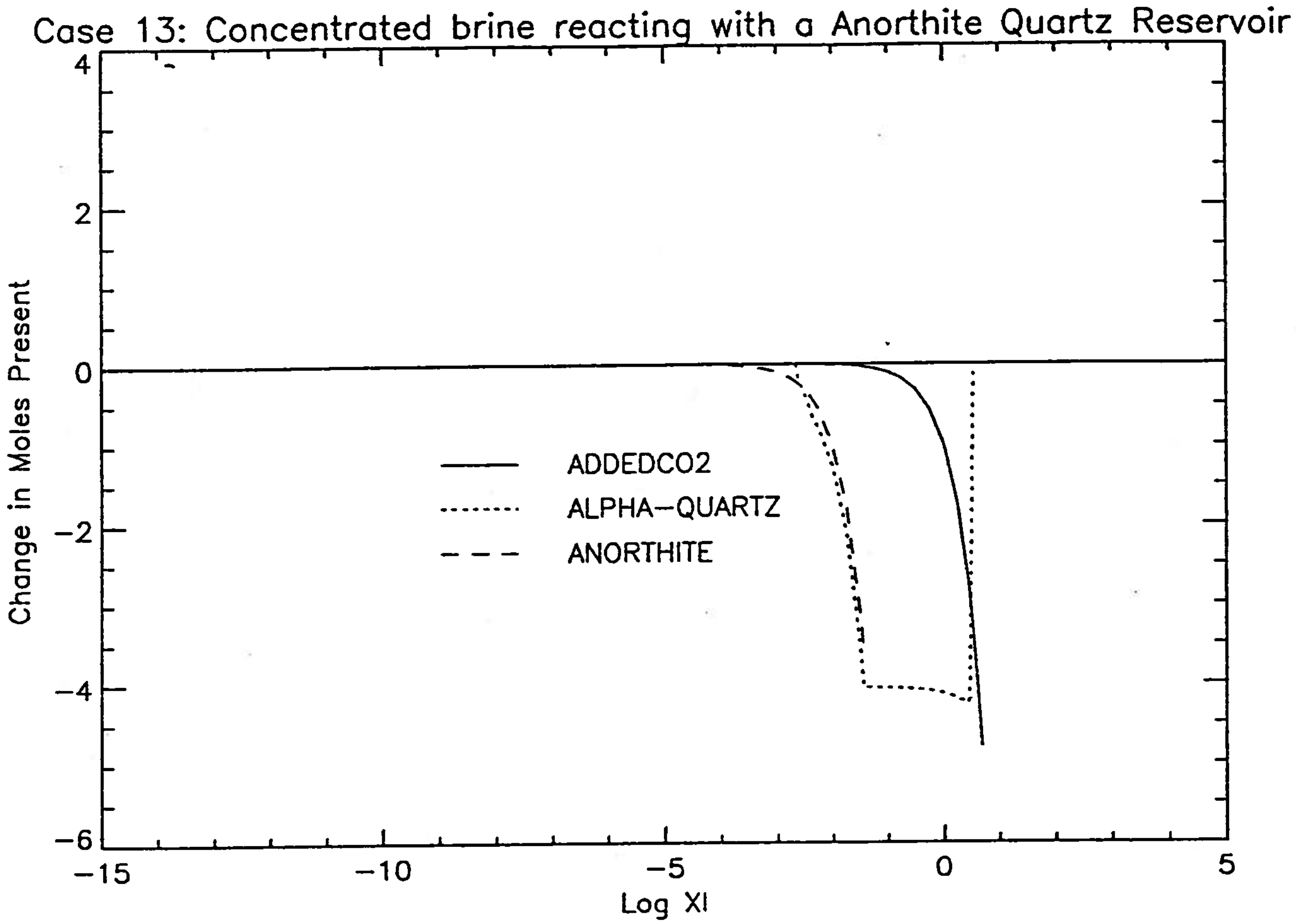

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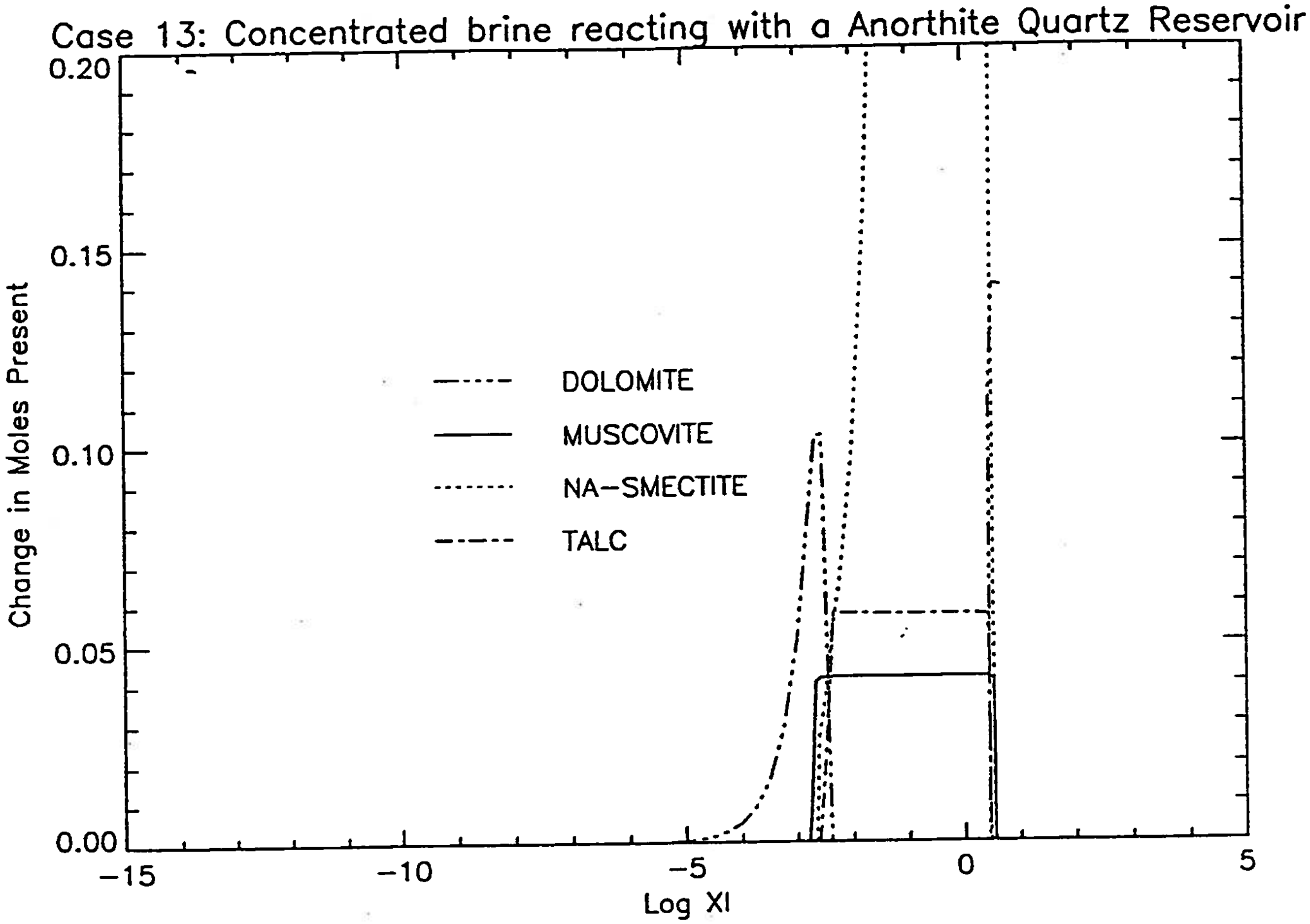

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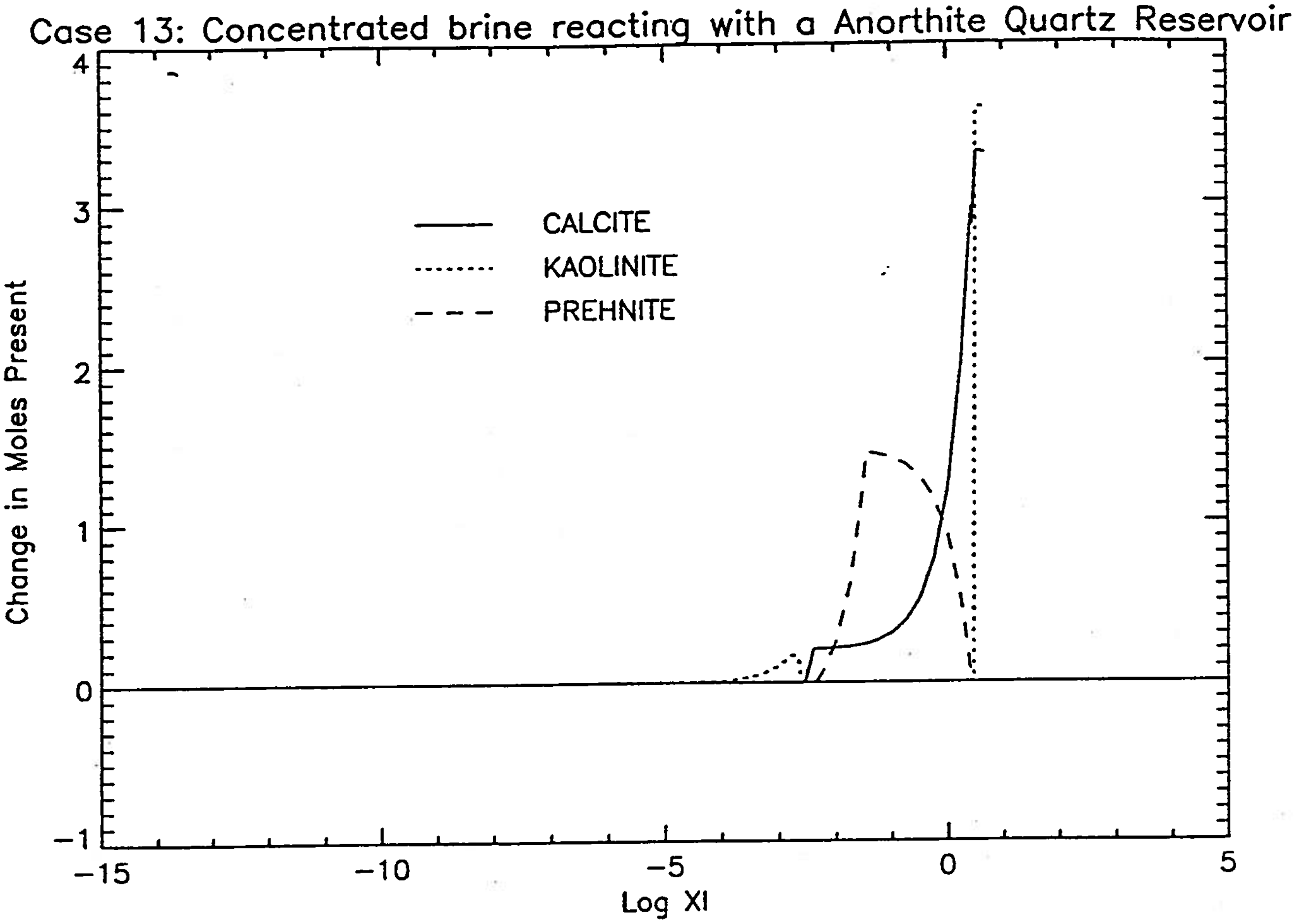

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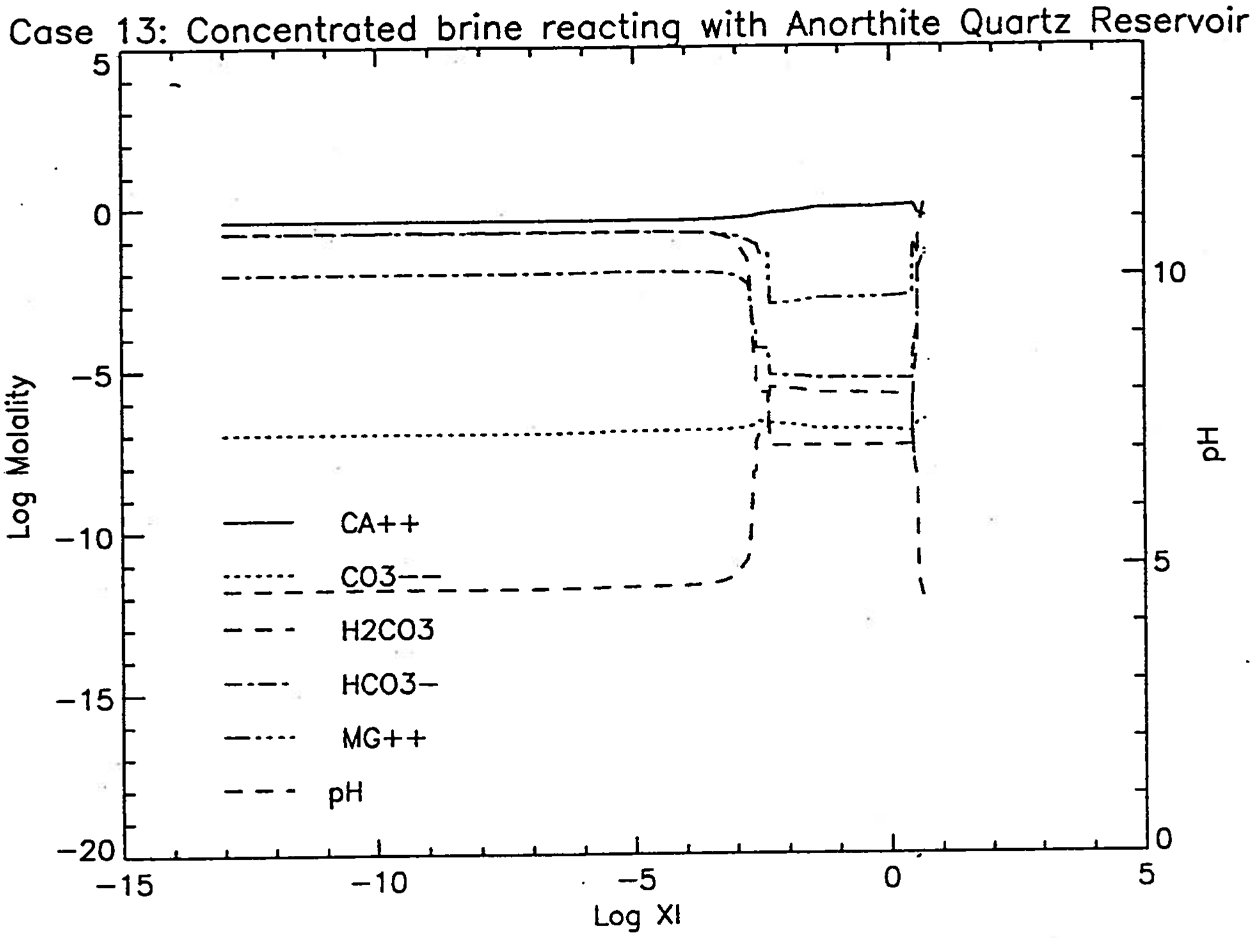


Figure 11.5.10c

Figure 11.5.11

Reaction of a Formation Water Brine with an anorthite-quartz siliciclastic aquifer at 100°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

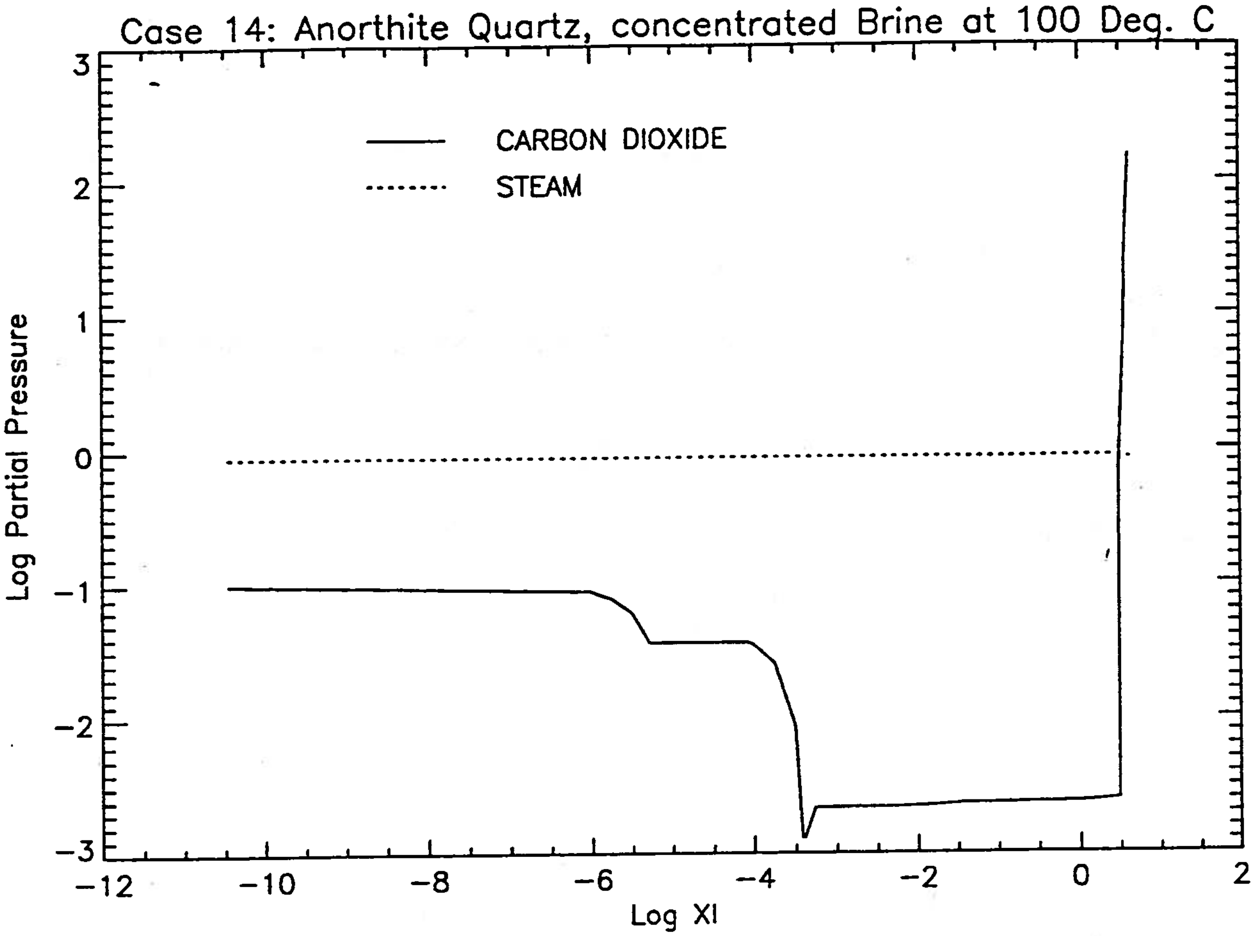
a: Buildup of the partial pressure of CO_2 in bars.

b1: Molar amount of CO_2 injected into the aquifer & change in the moles of mineral reactants.

b2: Change in the moles of mineral products.

b3: Change in the moles of mineral products.

c: Change in the molality of the aqueous species.



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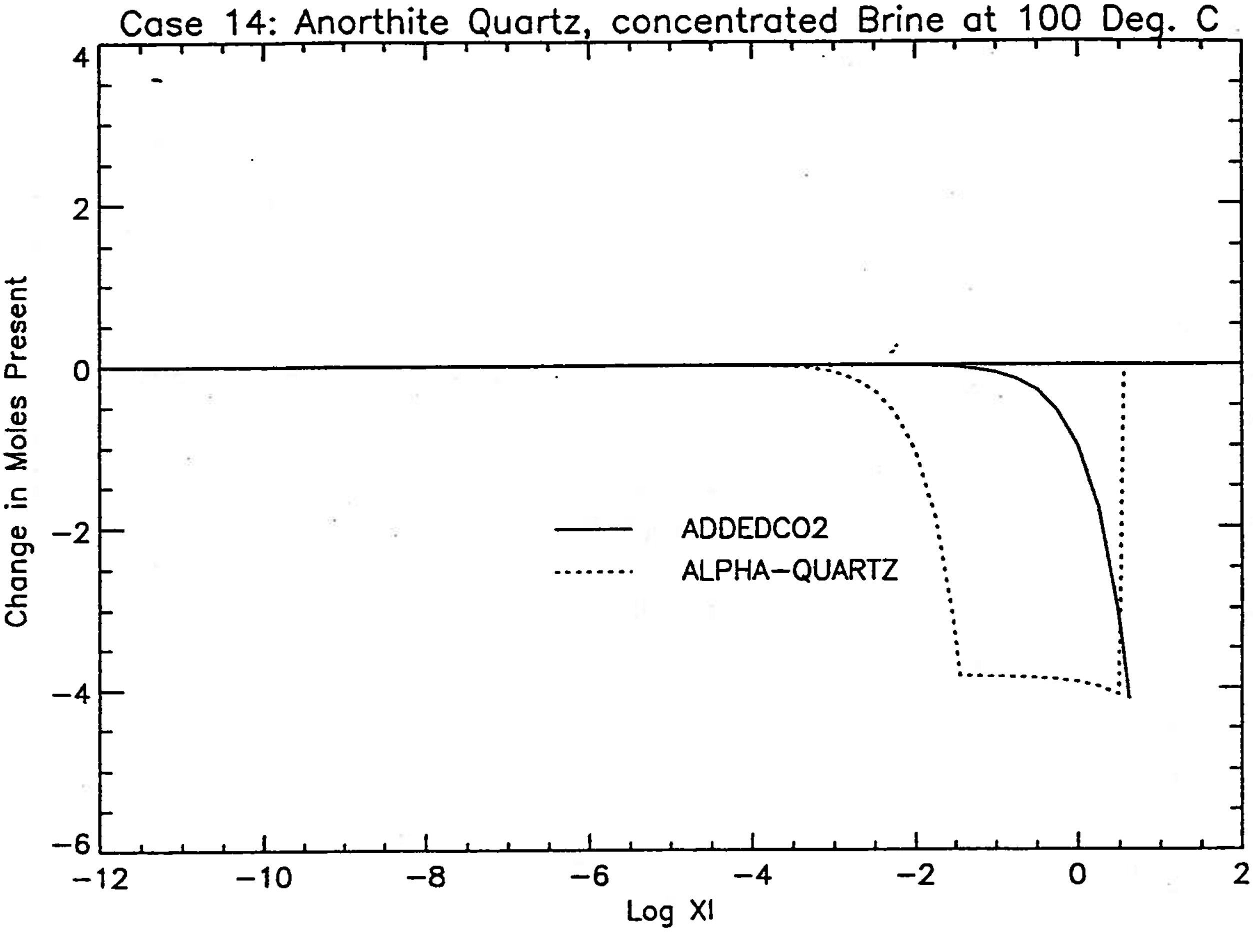

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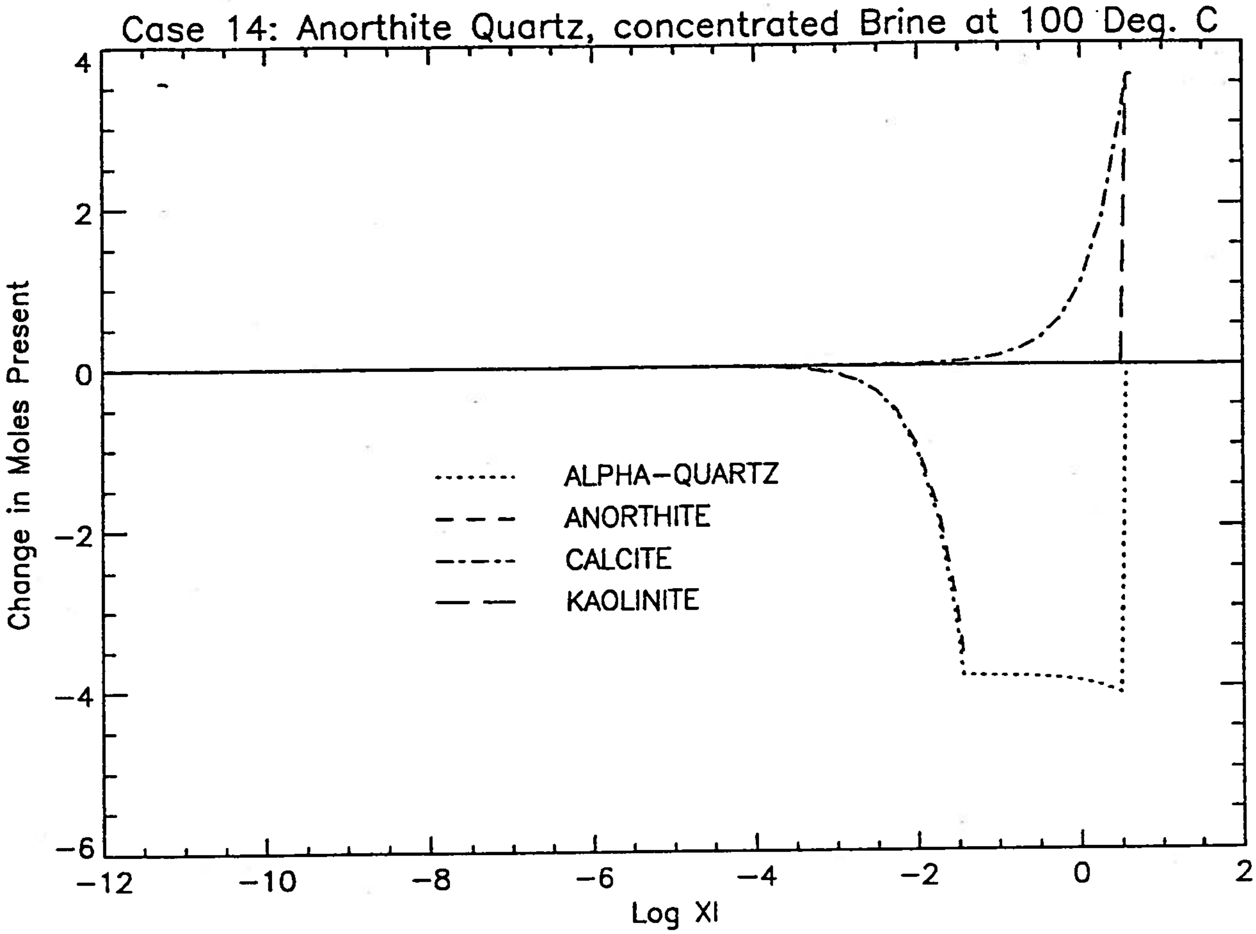

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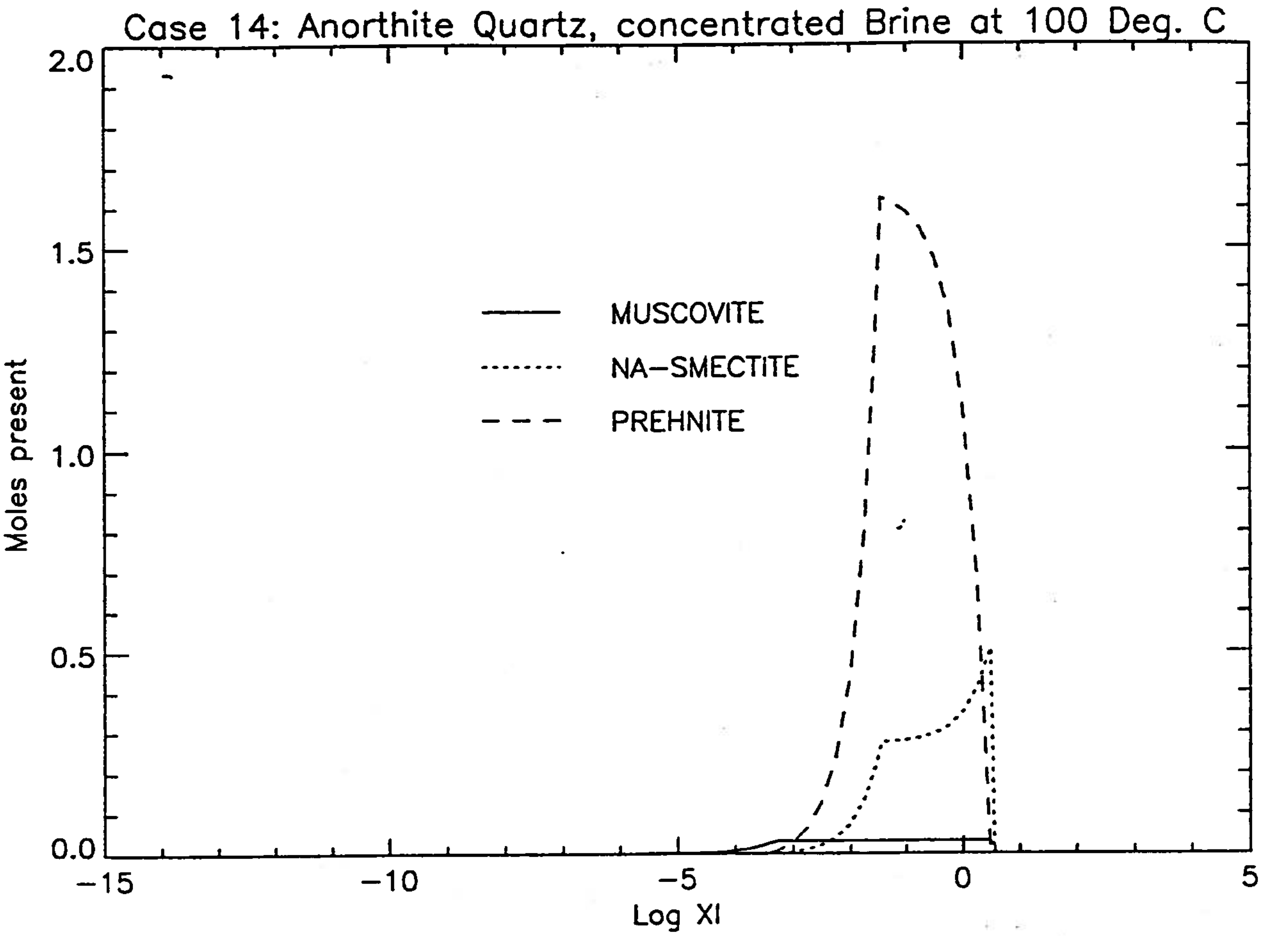

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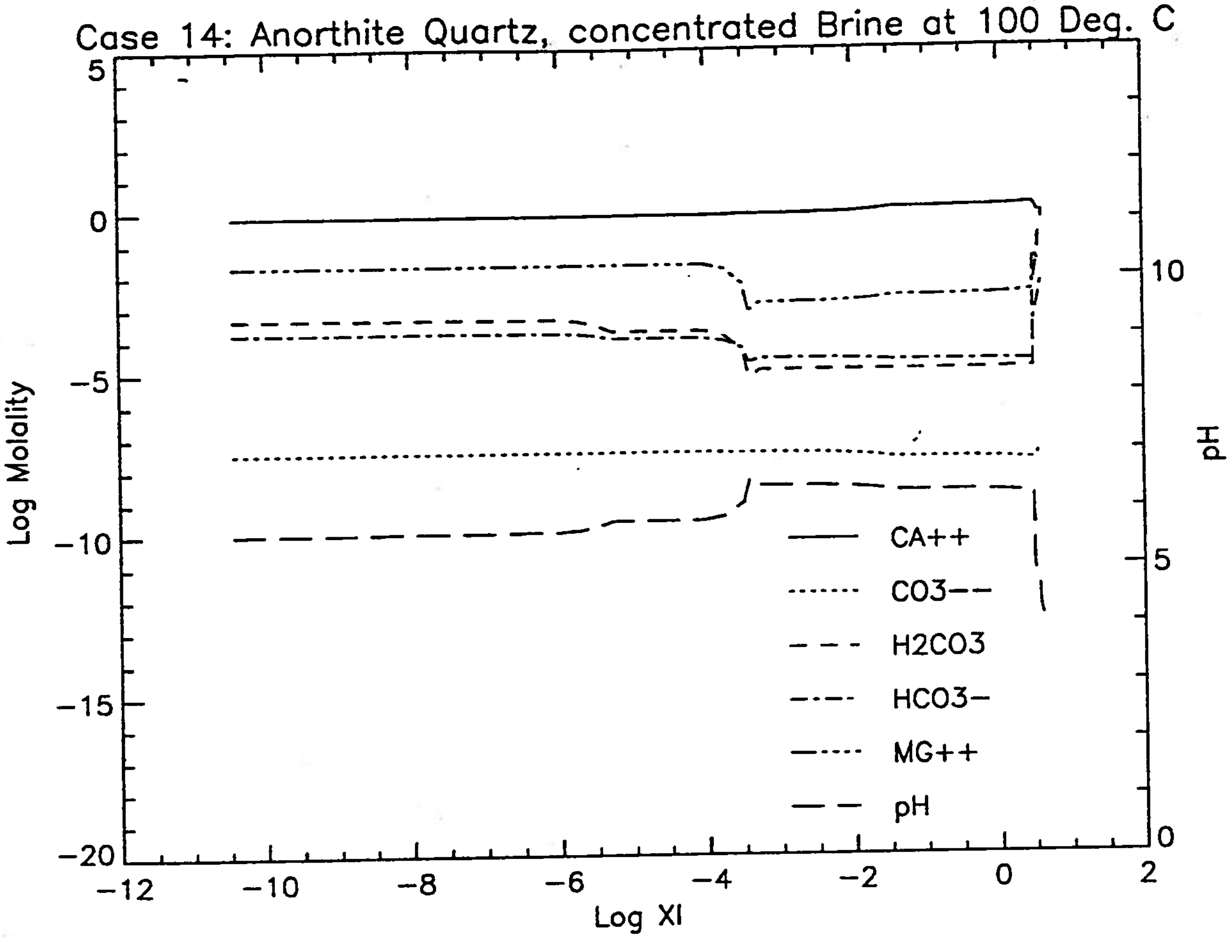


Figure 11.5.11c

Figure 11.5.12

Reaction of a Formation Water Brine with an anorthite-Ca.smectite-quartz-illite siliciclastic aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

a: Buildup of the partial pressure of CO_2 in bars.

b1: Molar amount of CO_2 injected into the aquifer.

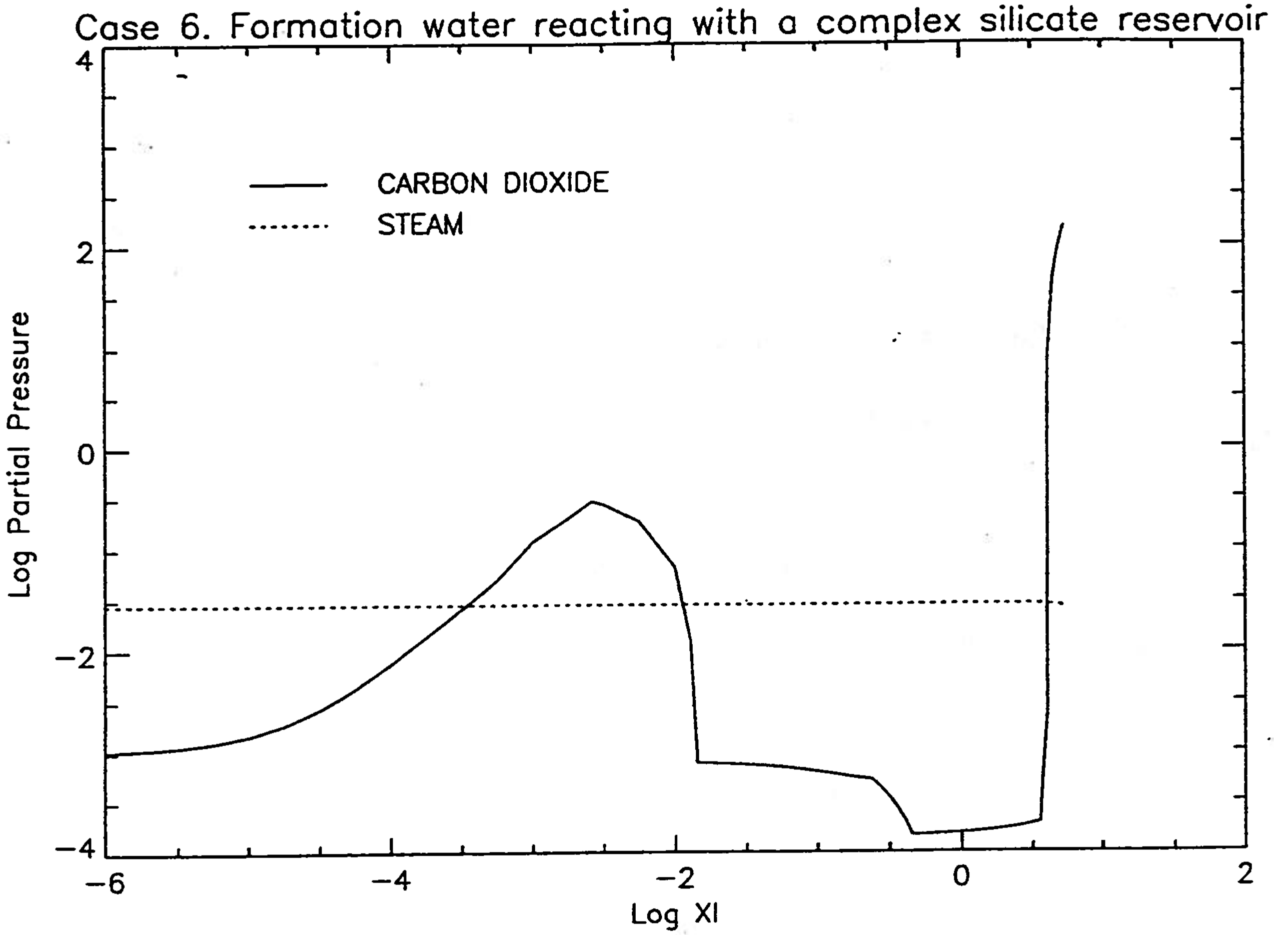
b2: Change in the moles of mineral reactants.

b3: Change in the moles of mineral reactants and products.

b4: Change in the moles of mineral products.

b5: Change in the moles of mineral products.

c: Change in the molality of the aqueous species.



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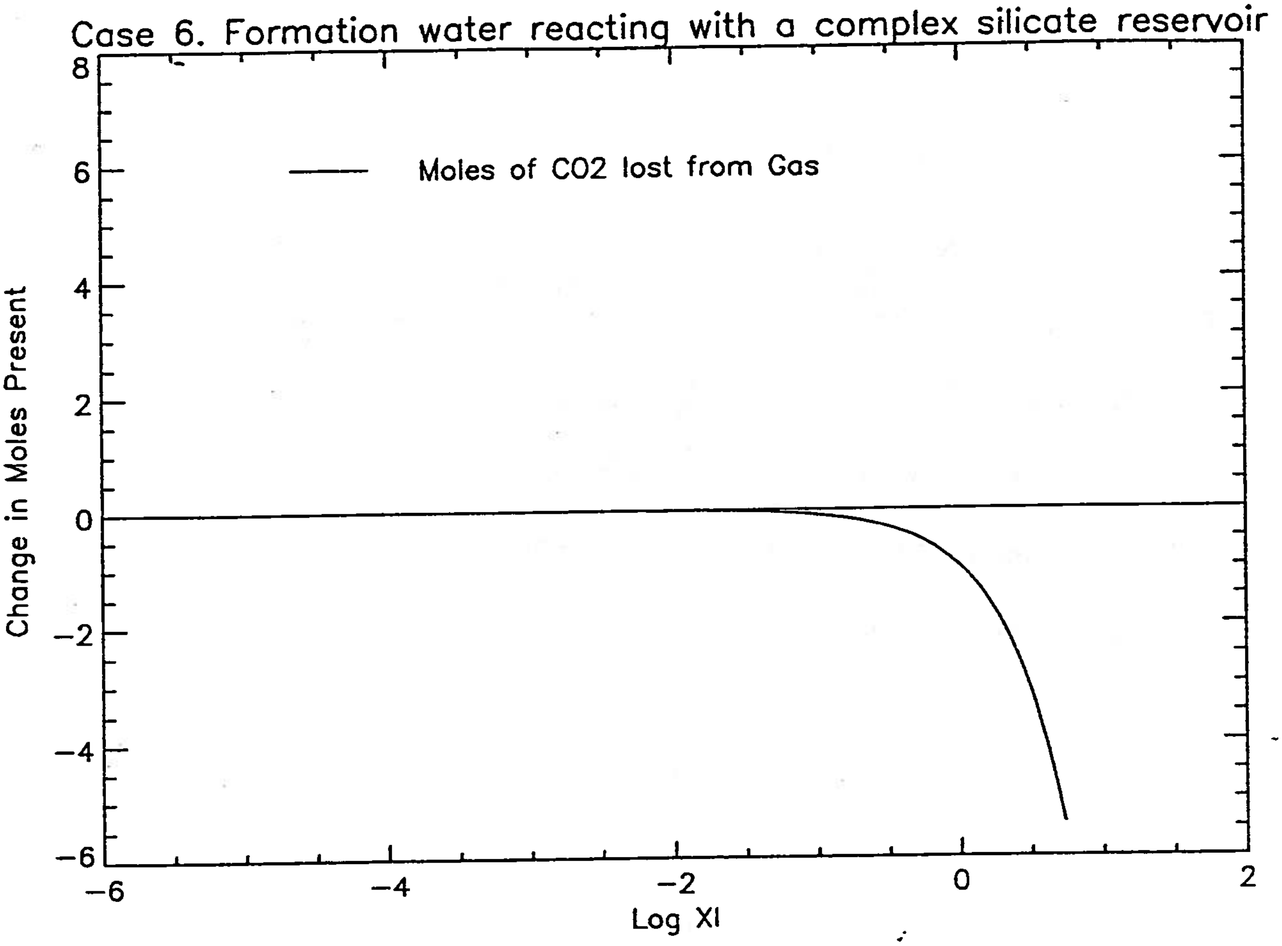


Figure 11.5.12b1

Figure 11.5.13

Reaction of a Formation Water Brine with an anorthite-Ca.smectite-quartz-illite siliciclastic aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI'). The water/rock ratio has been increased by an order of magnitude.

a: Buildup of the partial pressure of CO_2 in bars.

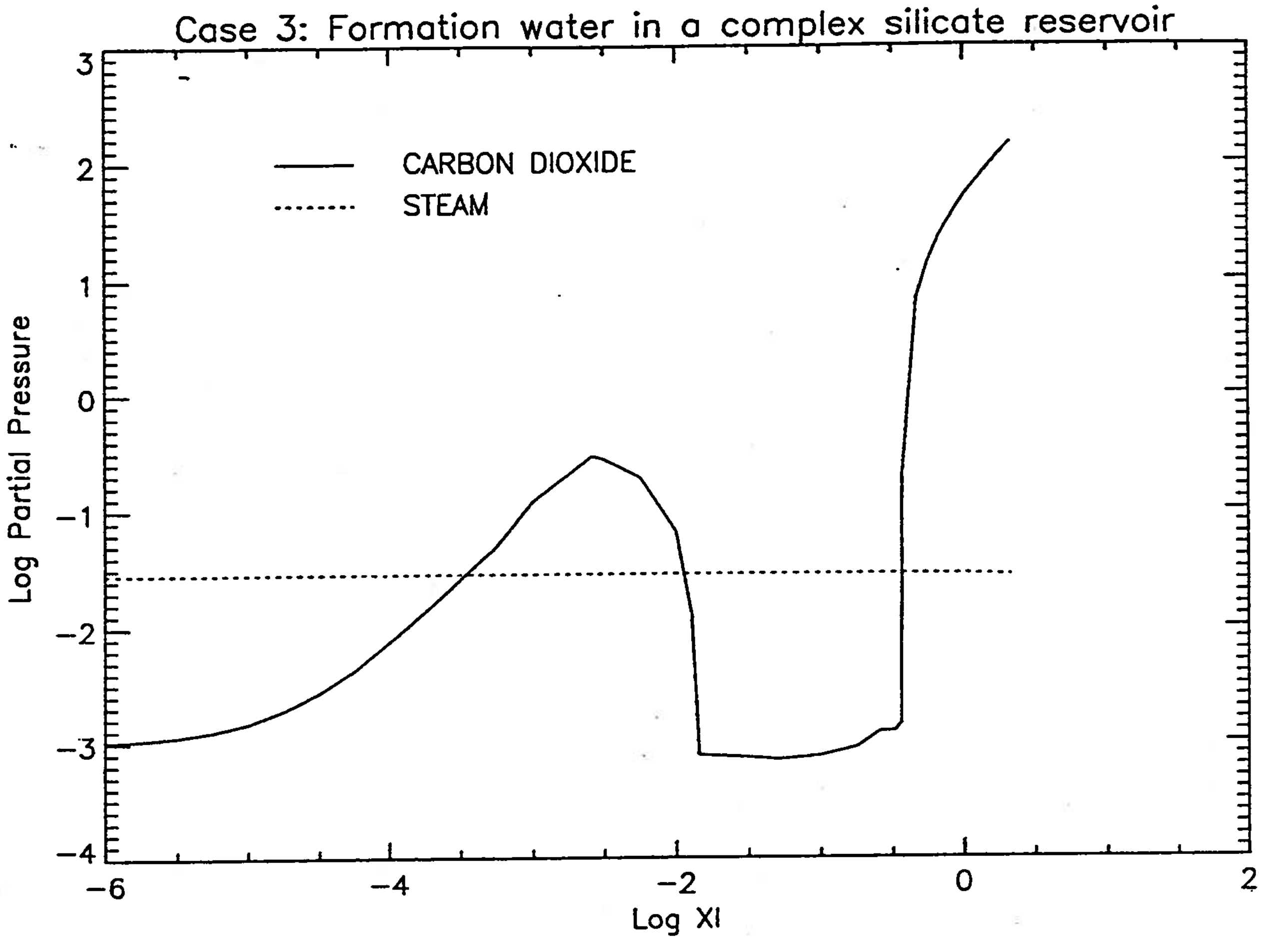
b1: Molar amount of CO_2 injected into the aquifer.

b2: Change in the moles of mineral reactants and products.

b3: Change in the moles of mineral reactants and products.

b4: Change in the moles of mineral products.

c: Change in the molality of the aqueous species.



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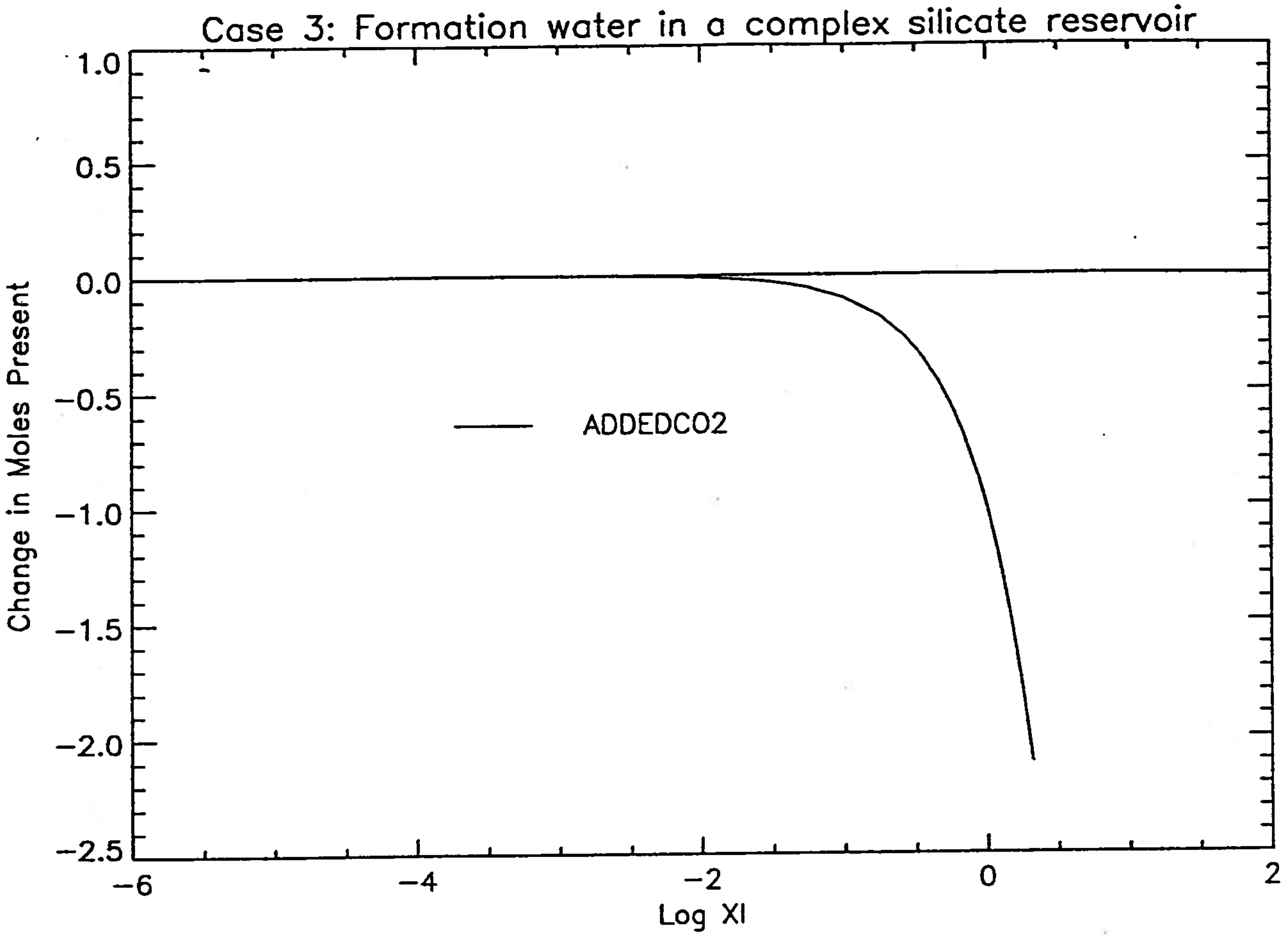

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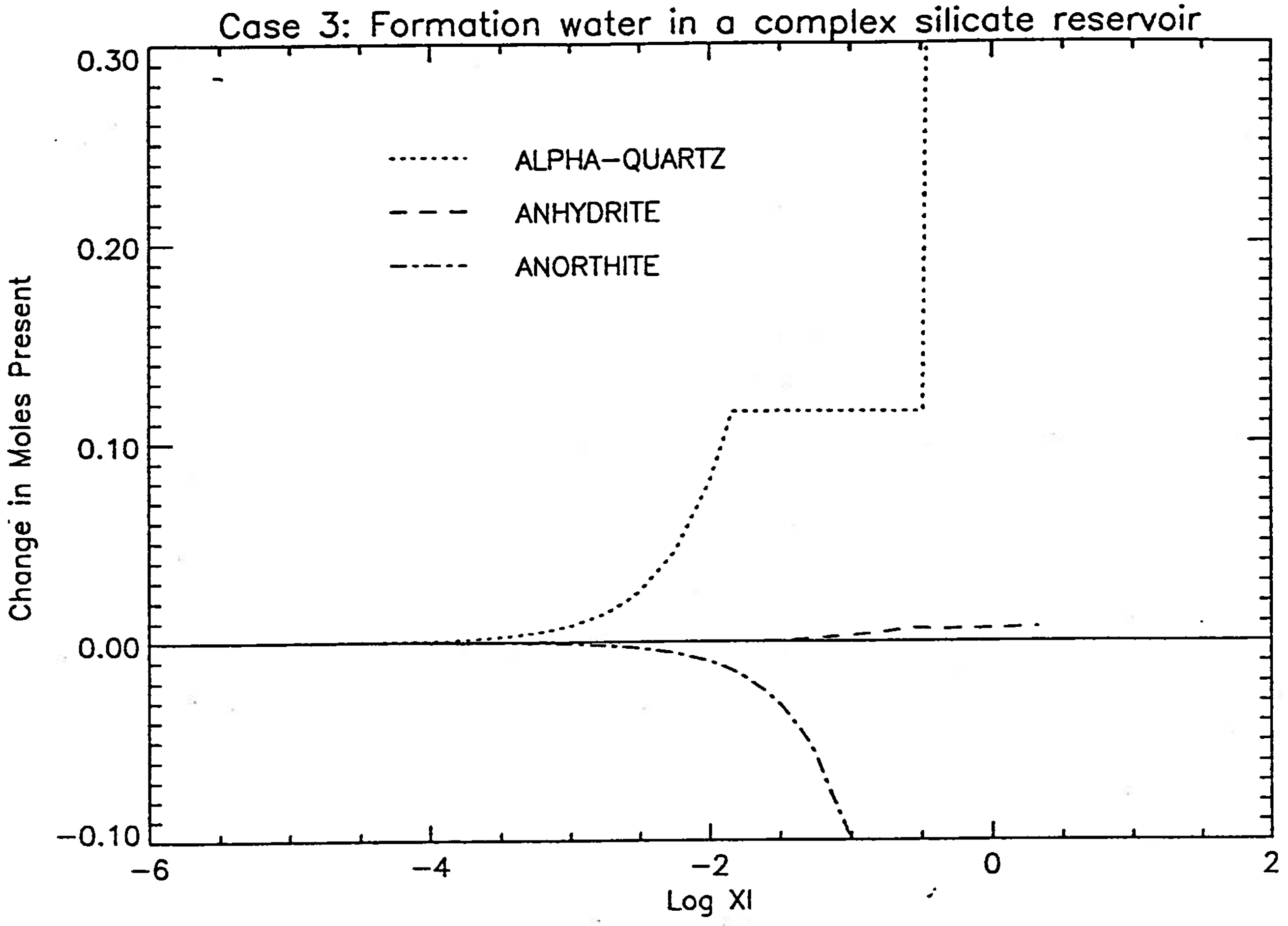

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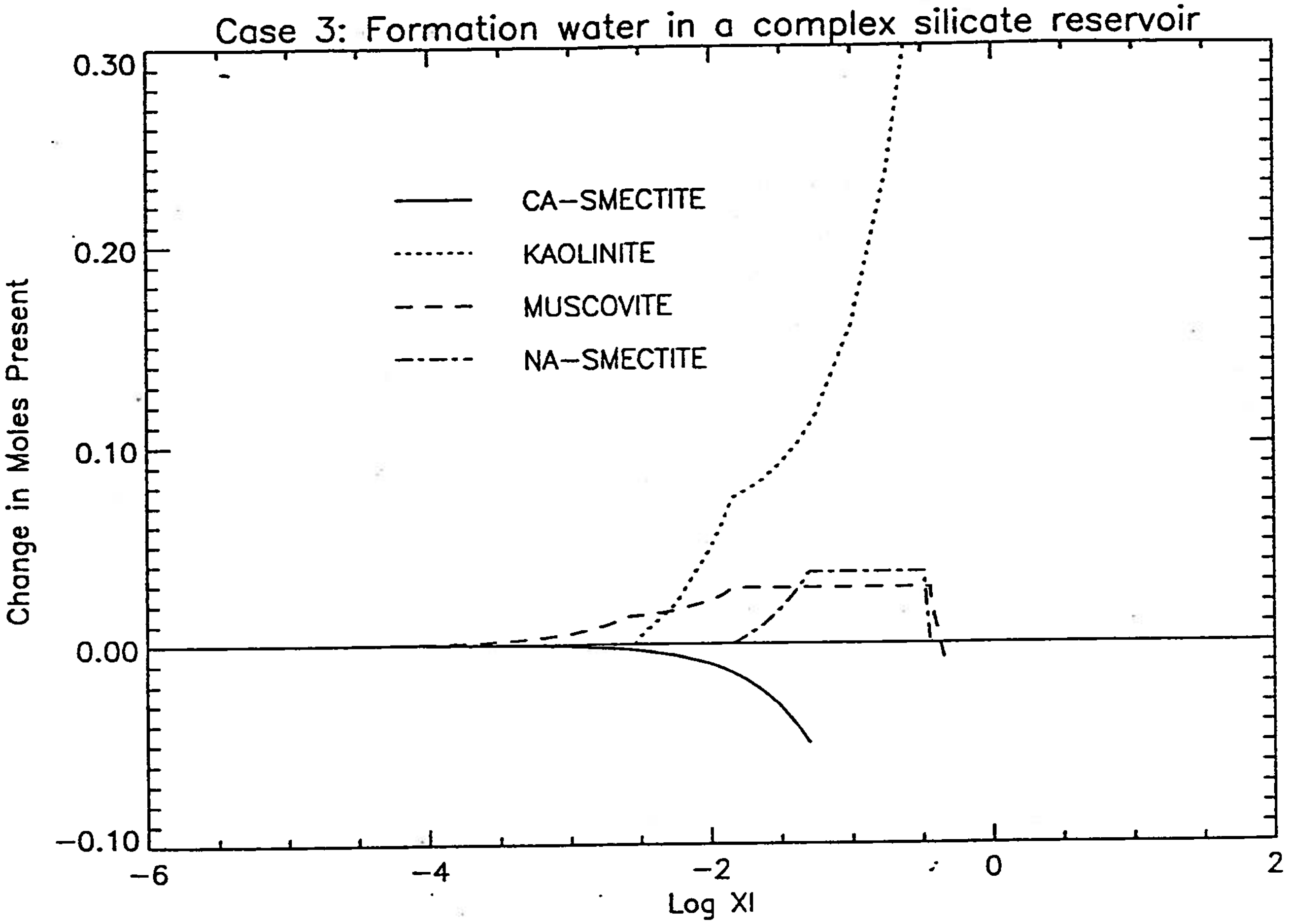

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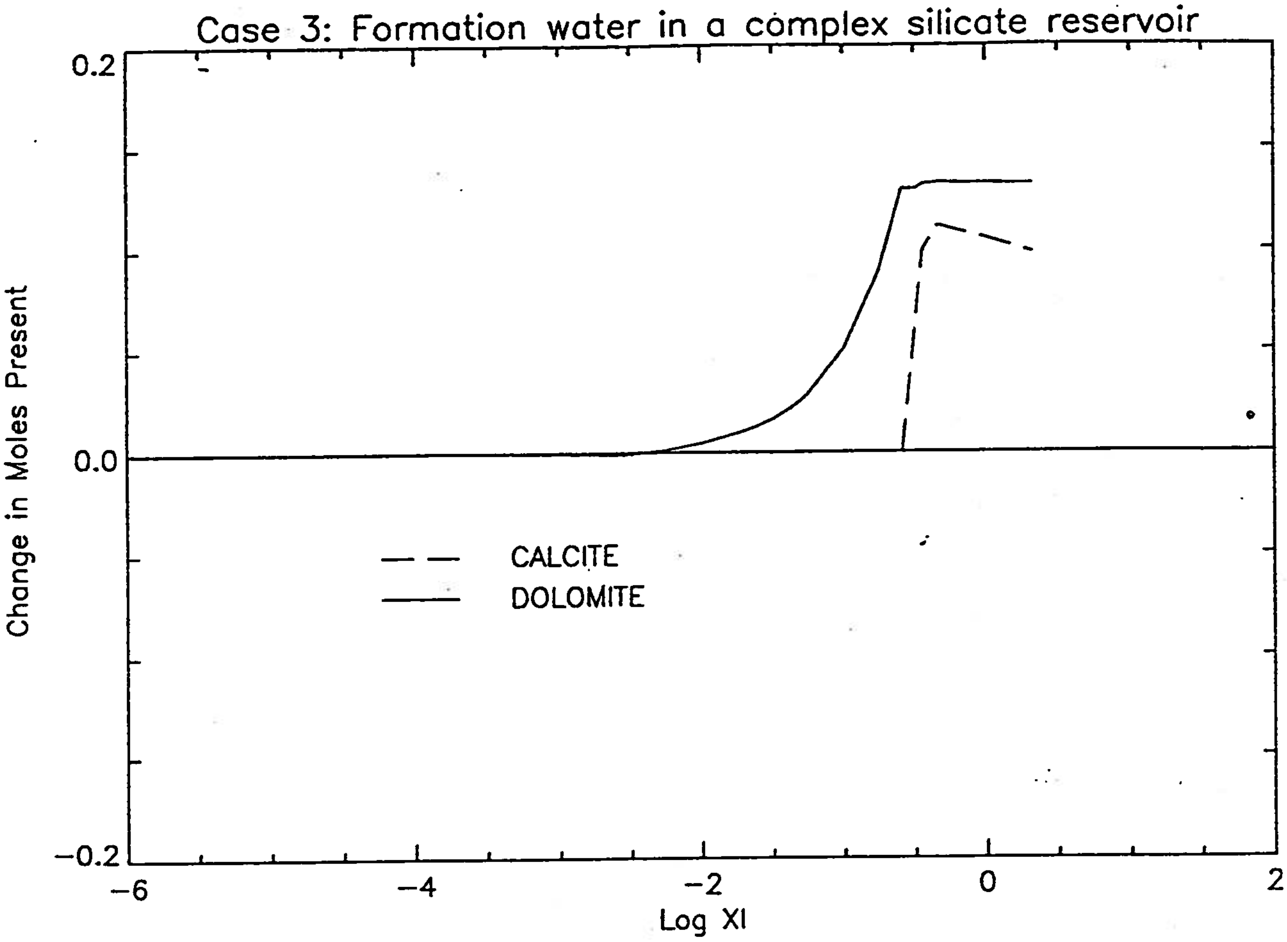

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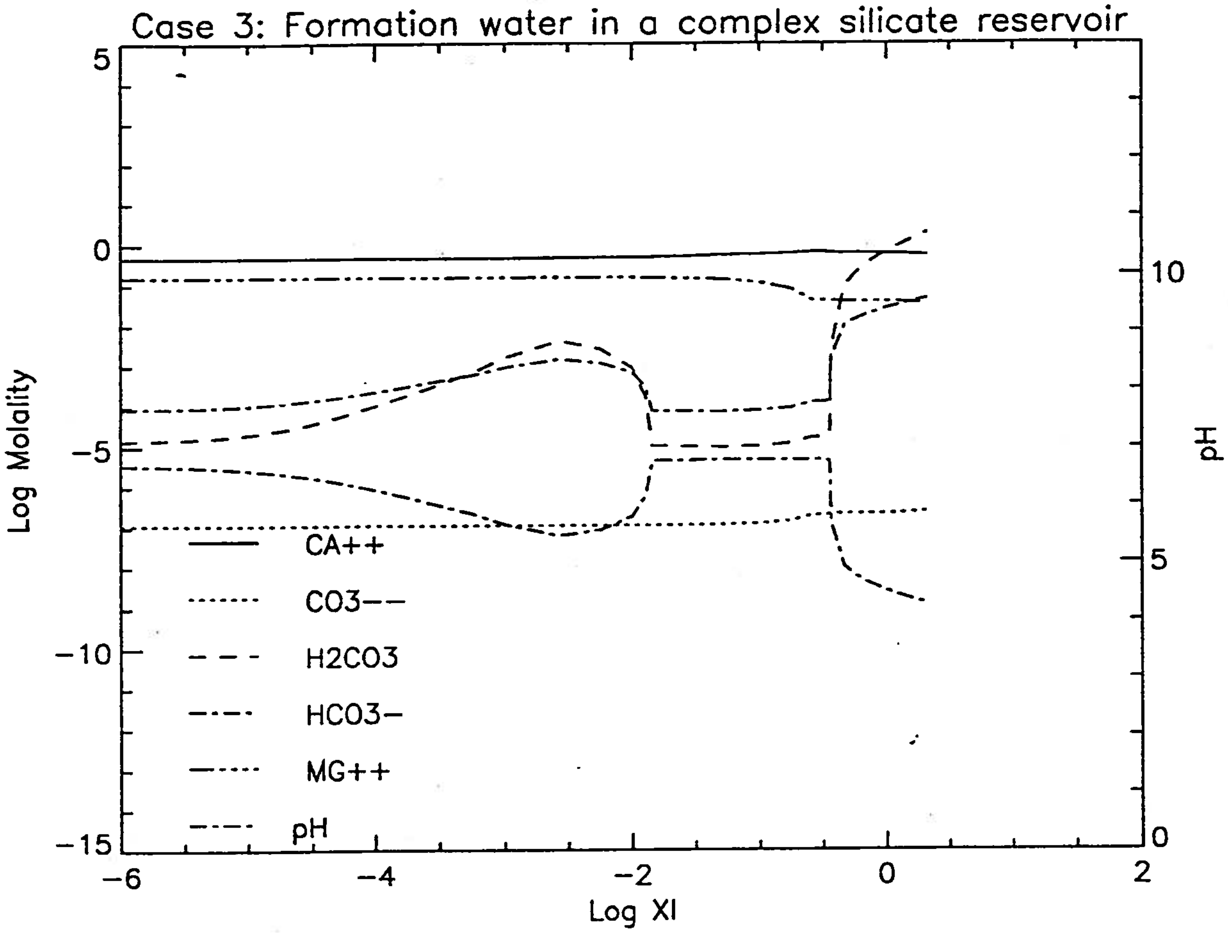


Figure 11.5.13c

Figure 11.5.14

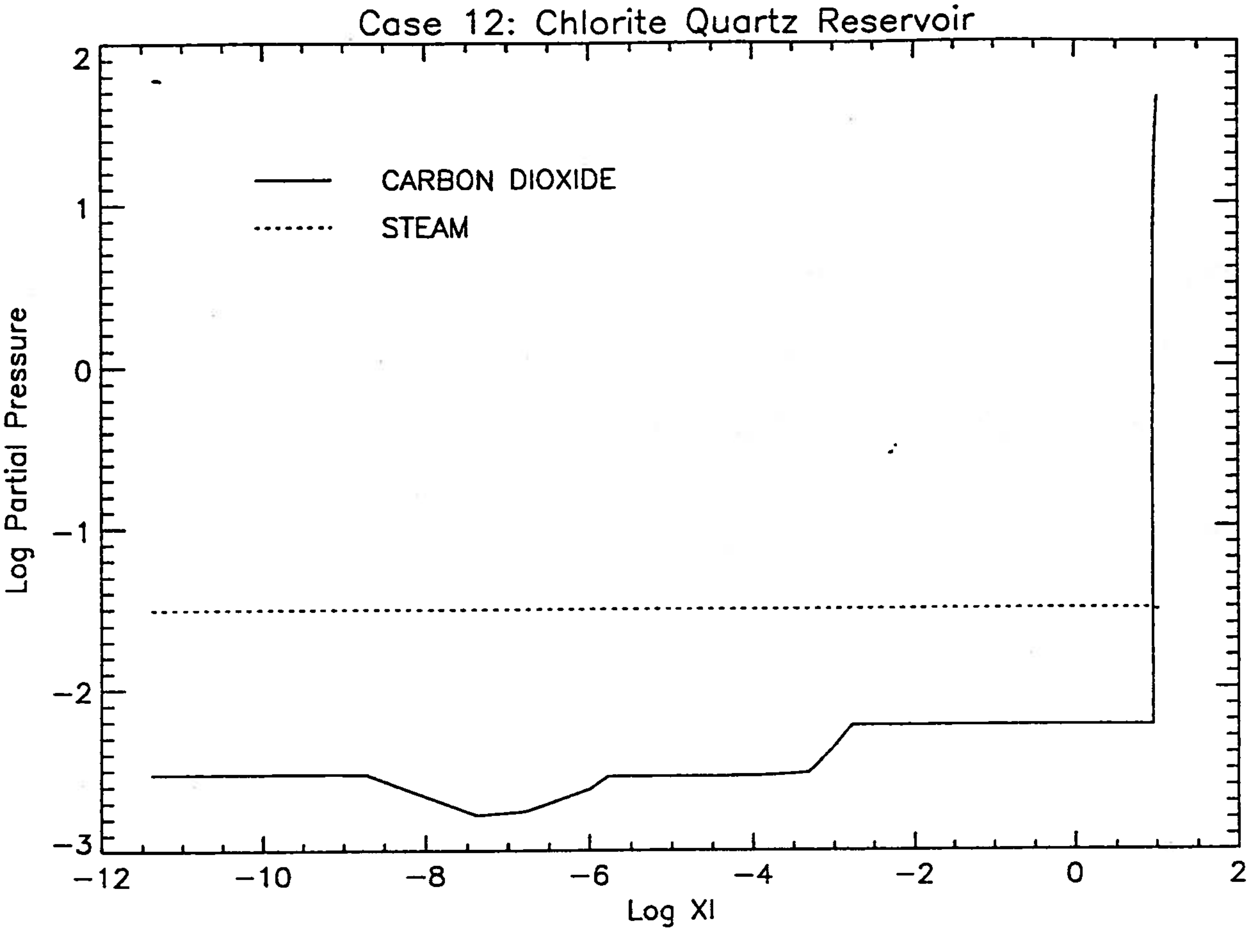
Reaction of a Brackish Formation Water with an clinochlore-quartz siliciclastic aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

a: Buildup of the partial pressure of CO_2 in bars.

b1: Molar amount of CO_2 injected into the aquifer & change in the moles of mineral reactants and products.

b2: Change in the moles of mineral products.

c: Change in the molality of the aqueous species.



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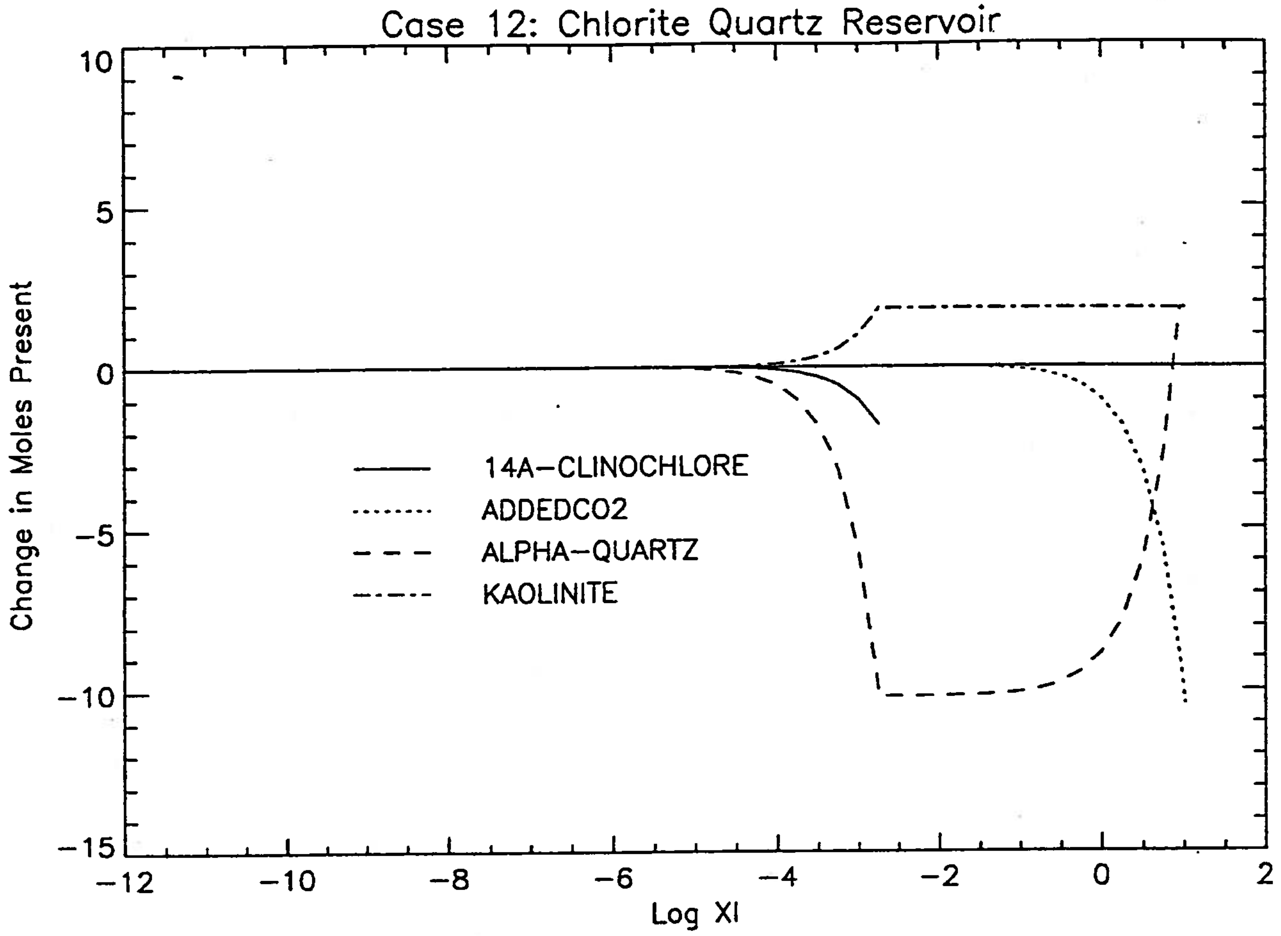

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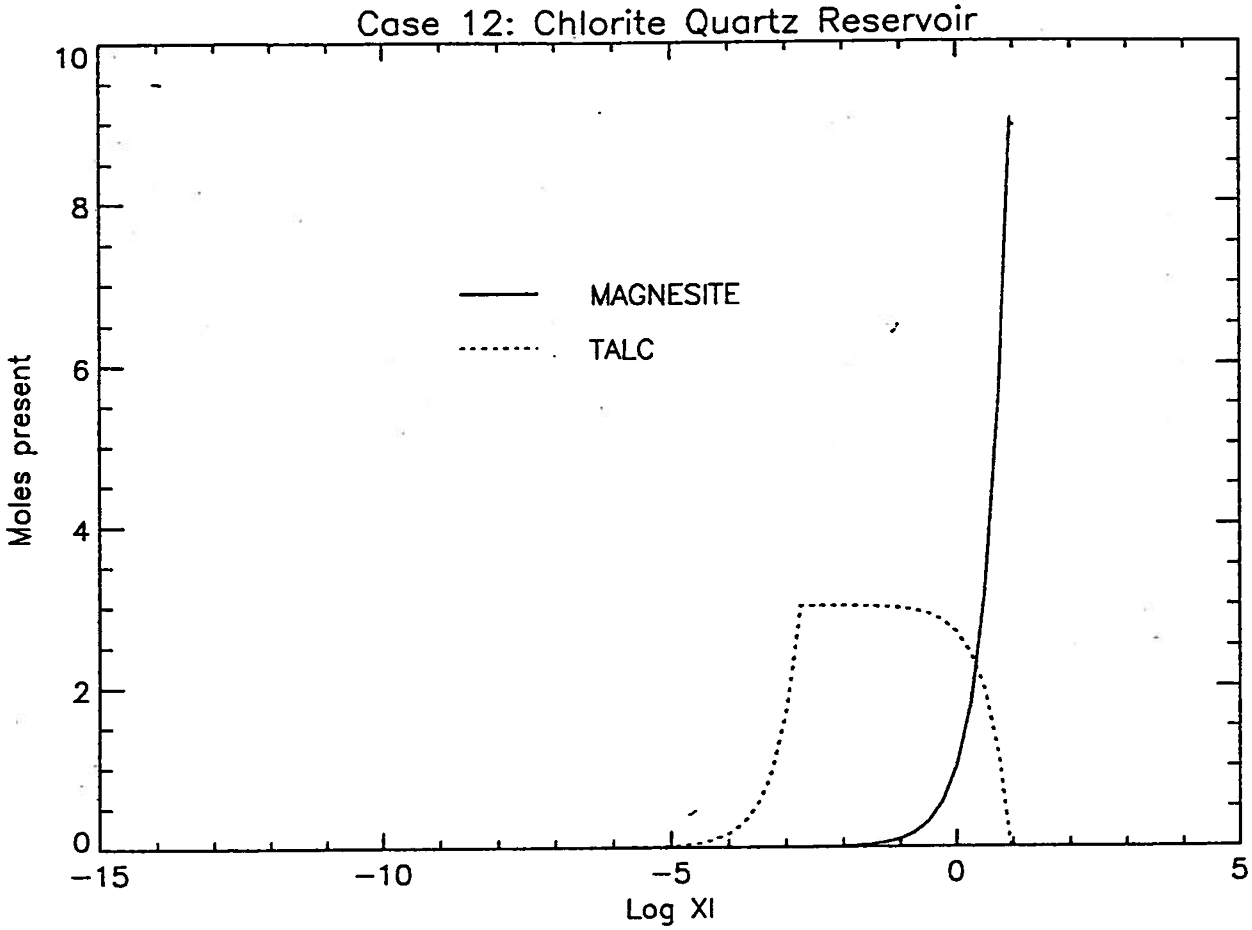

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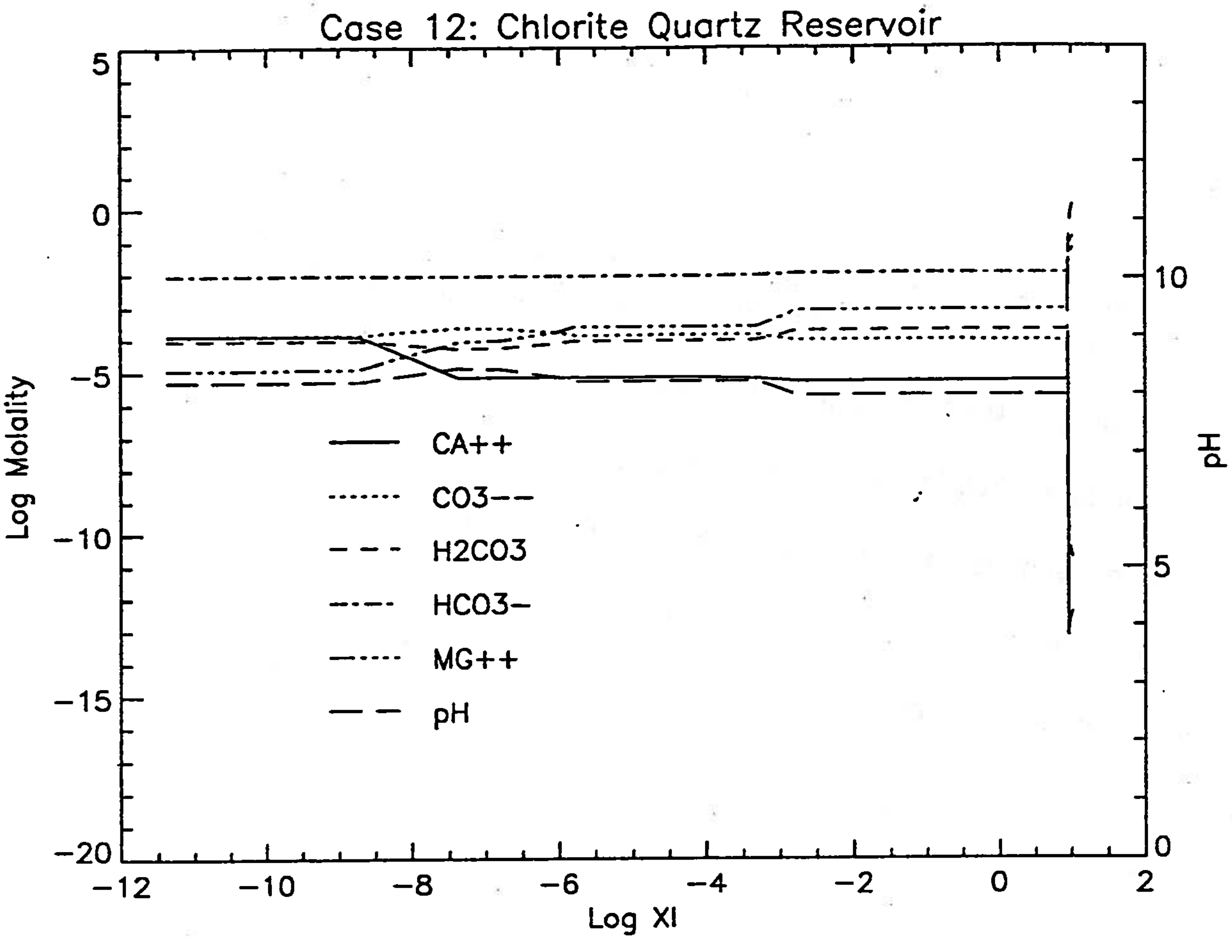


Figure 11.5.14c

Figure 11.5.15

Reaction of a Brackish Formation Water with an albite-quartz-illite siliciclastic aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

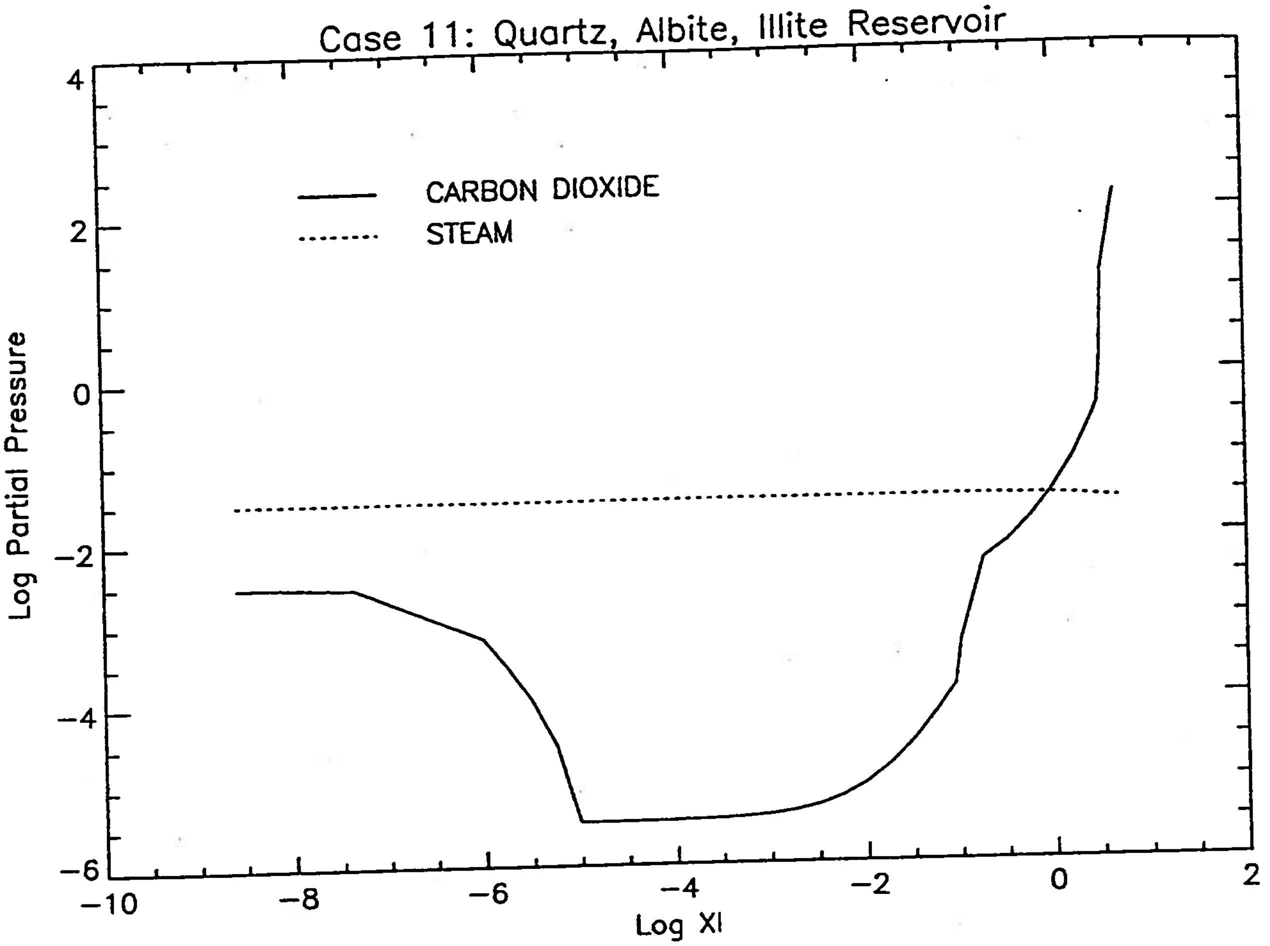
a: Buildup of the partial pressure of CO_2 in bars.

b1: Molar amount of CO_2 injected into the aquifer.

b2: Change in the moles of mineral reactants and products.

b3: Change in the moles of mineral products.

c: Change in the molality of the aqueous species.



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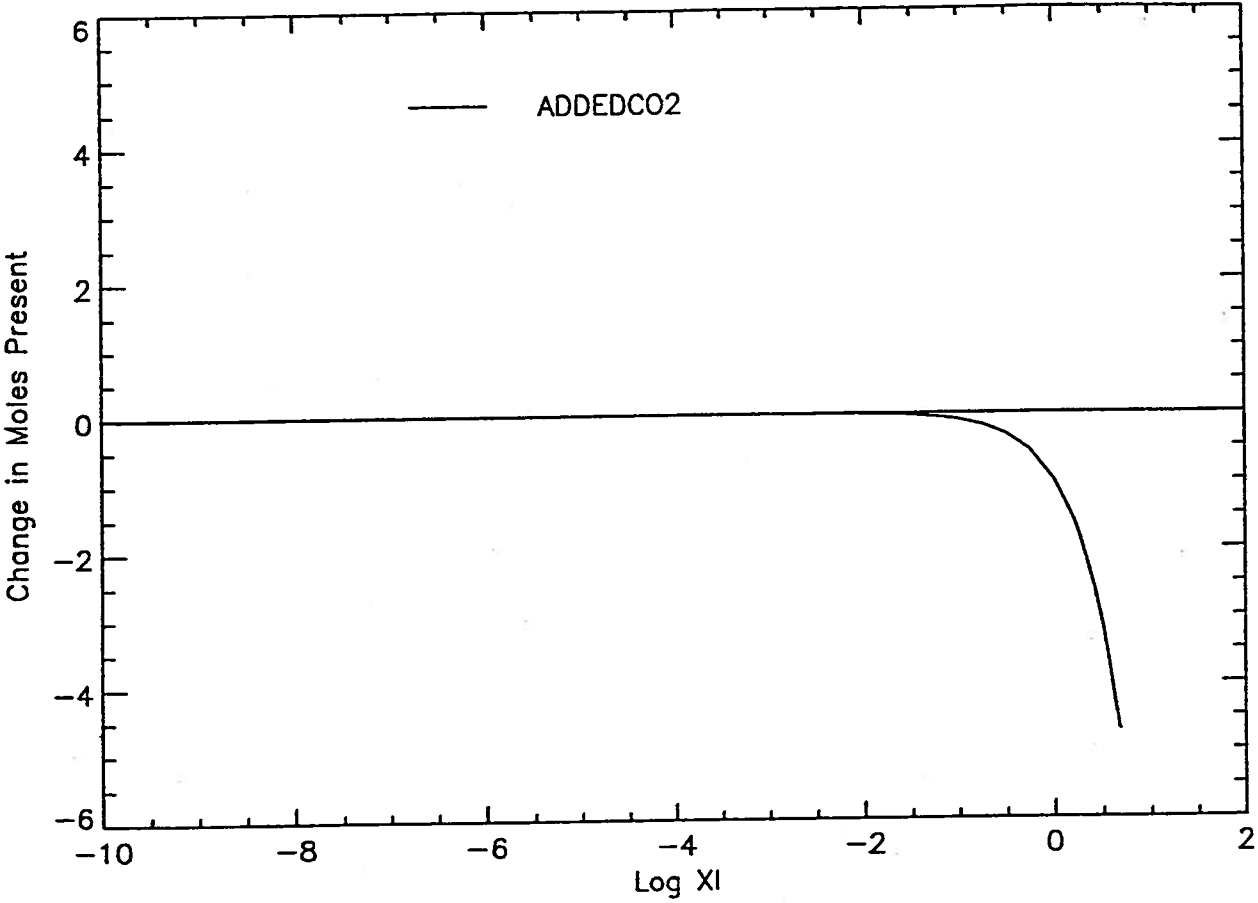

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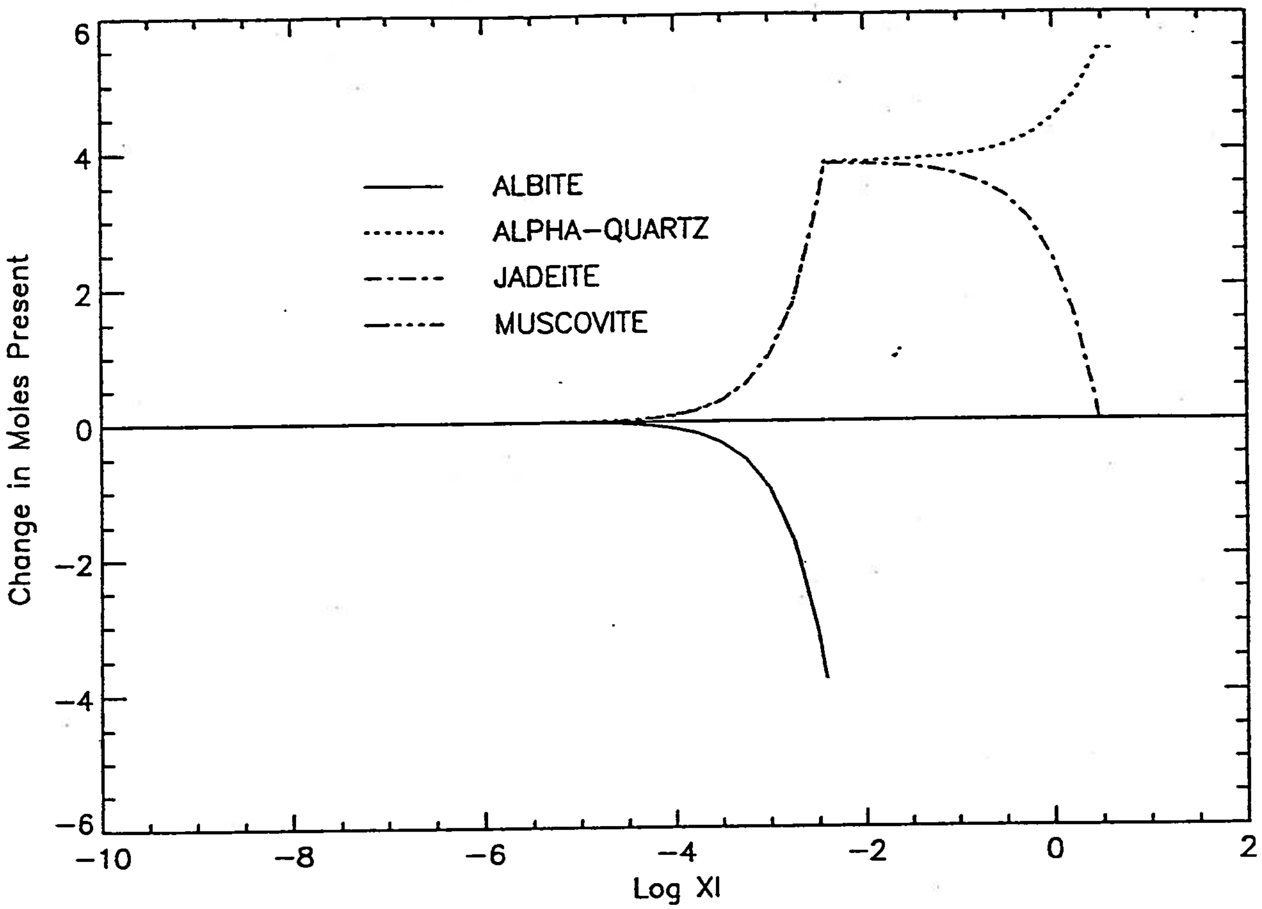

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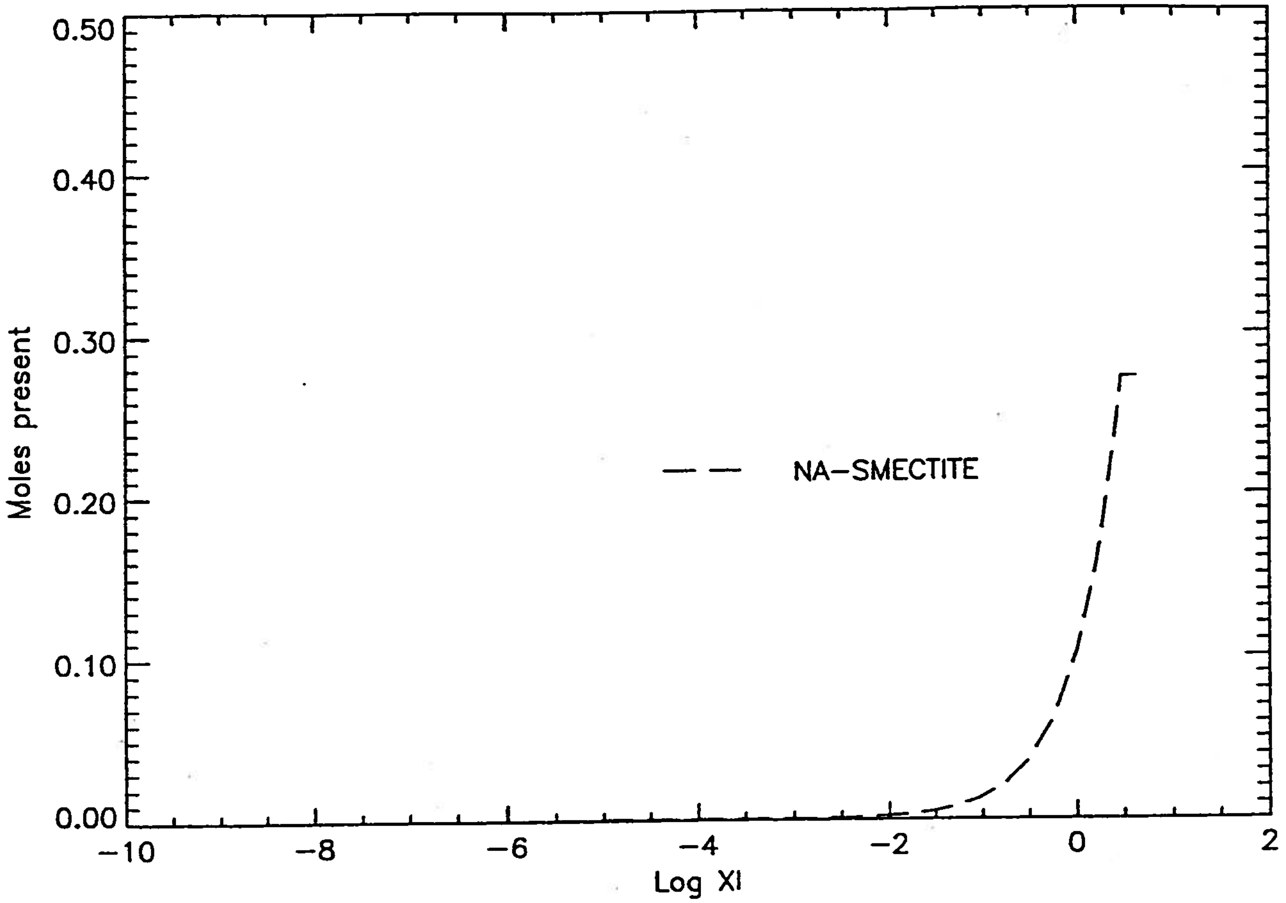

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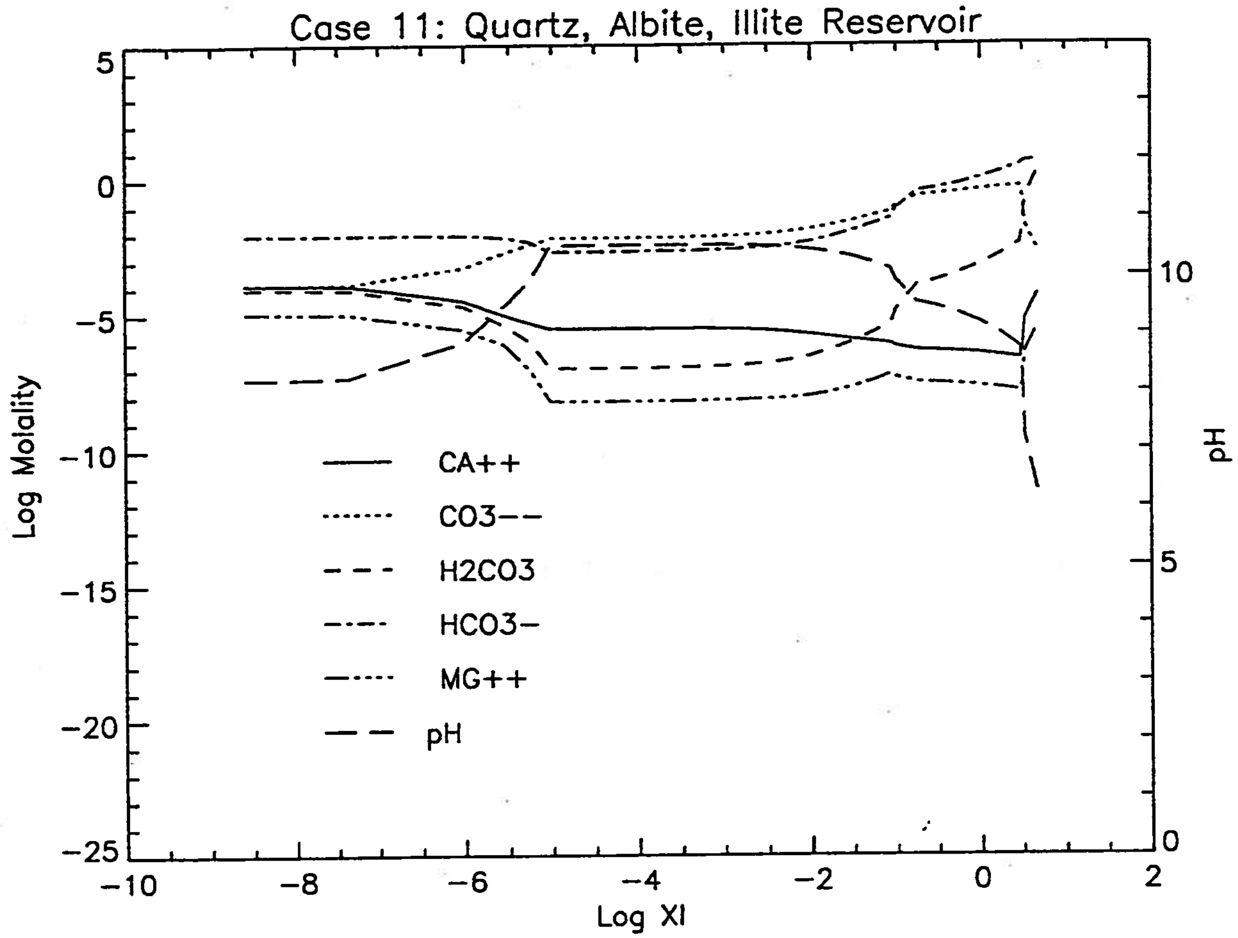


Figure 11.5.15c

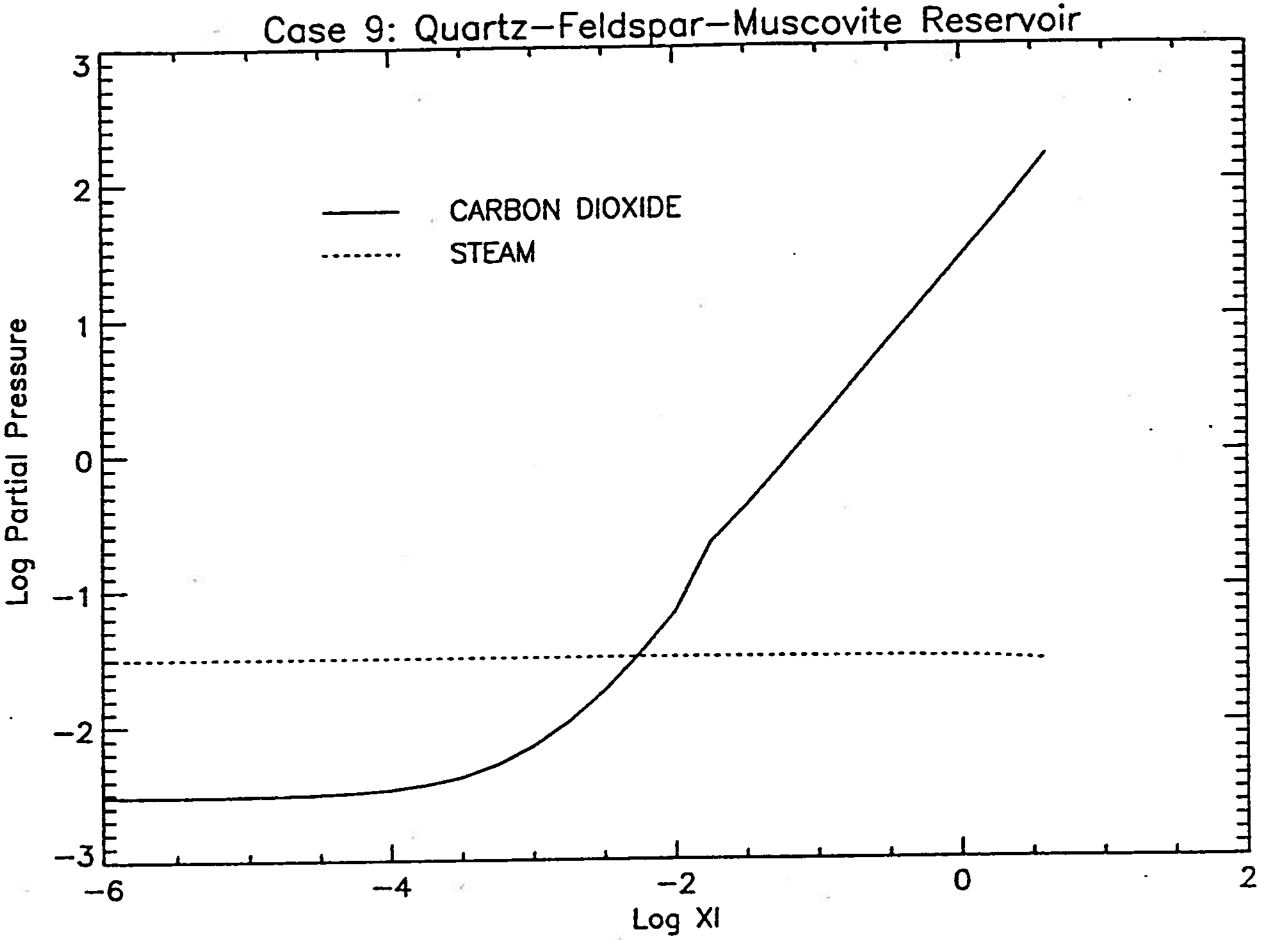
Figure 11.5.16

Reaction of a Brackish Formation Water with an K.feldspar-quartz-illite siliciclastic aquifer at 25°C as CO_2 is injected into the aquifer; plotted as a function of time ('XI').

a: Buildup of the partial pressure of CO_2 in bars.

b: Molar amount of CO_2 injected into the aquifer & change in the moles of mineral reactants.

c: Change in the molality of the aqueous species.



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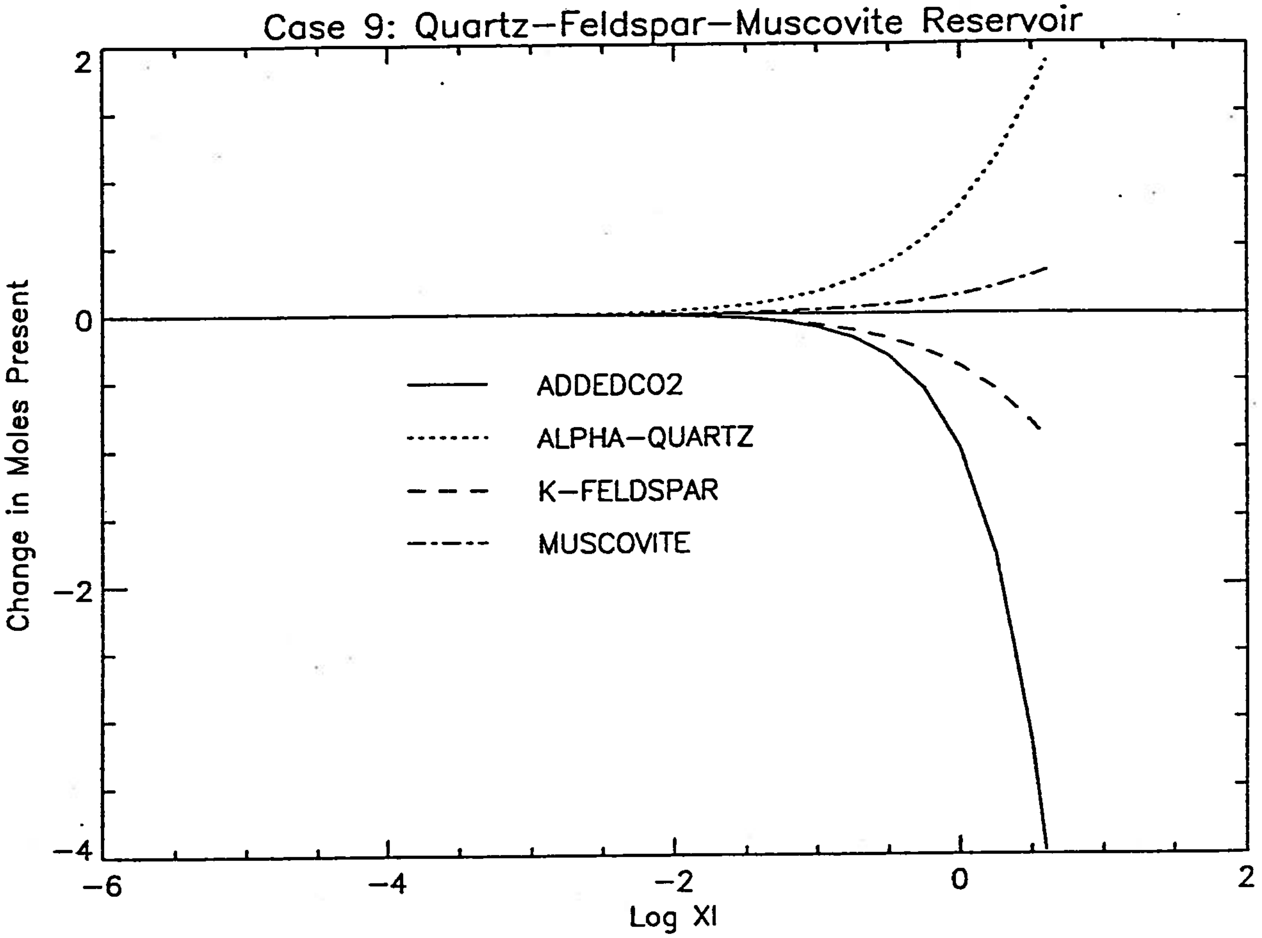

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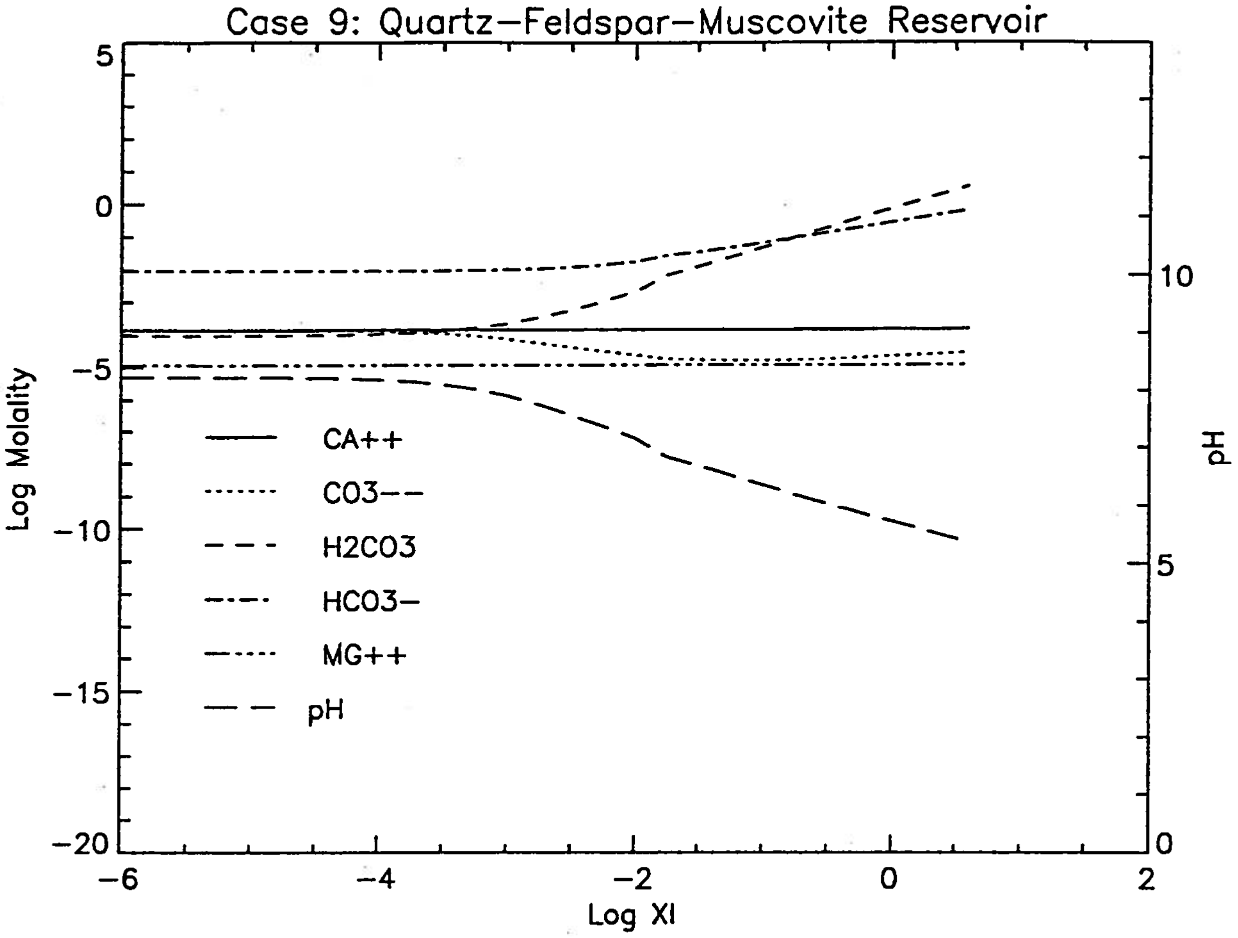

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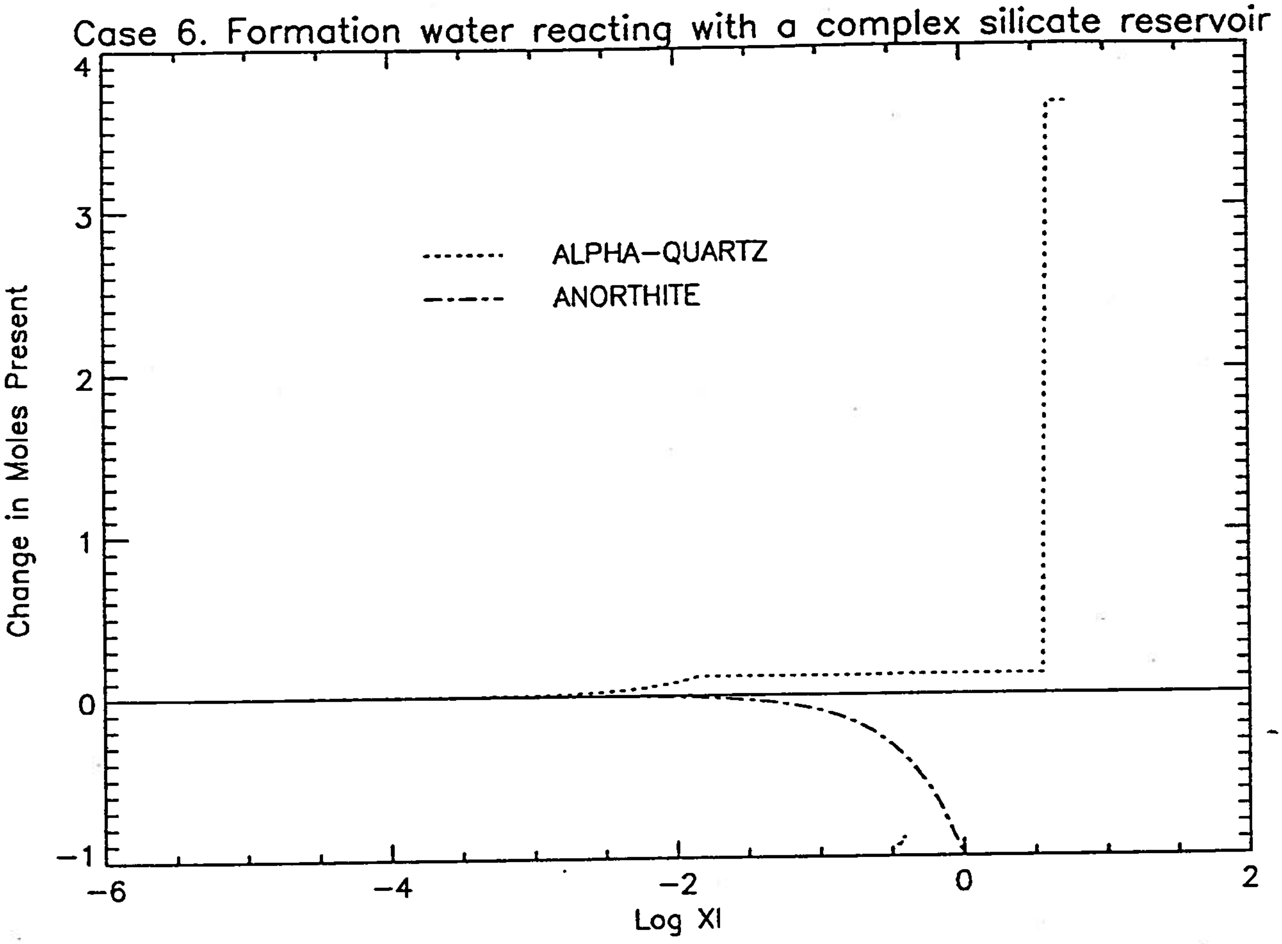

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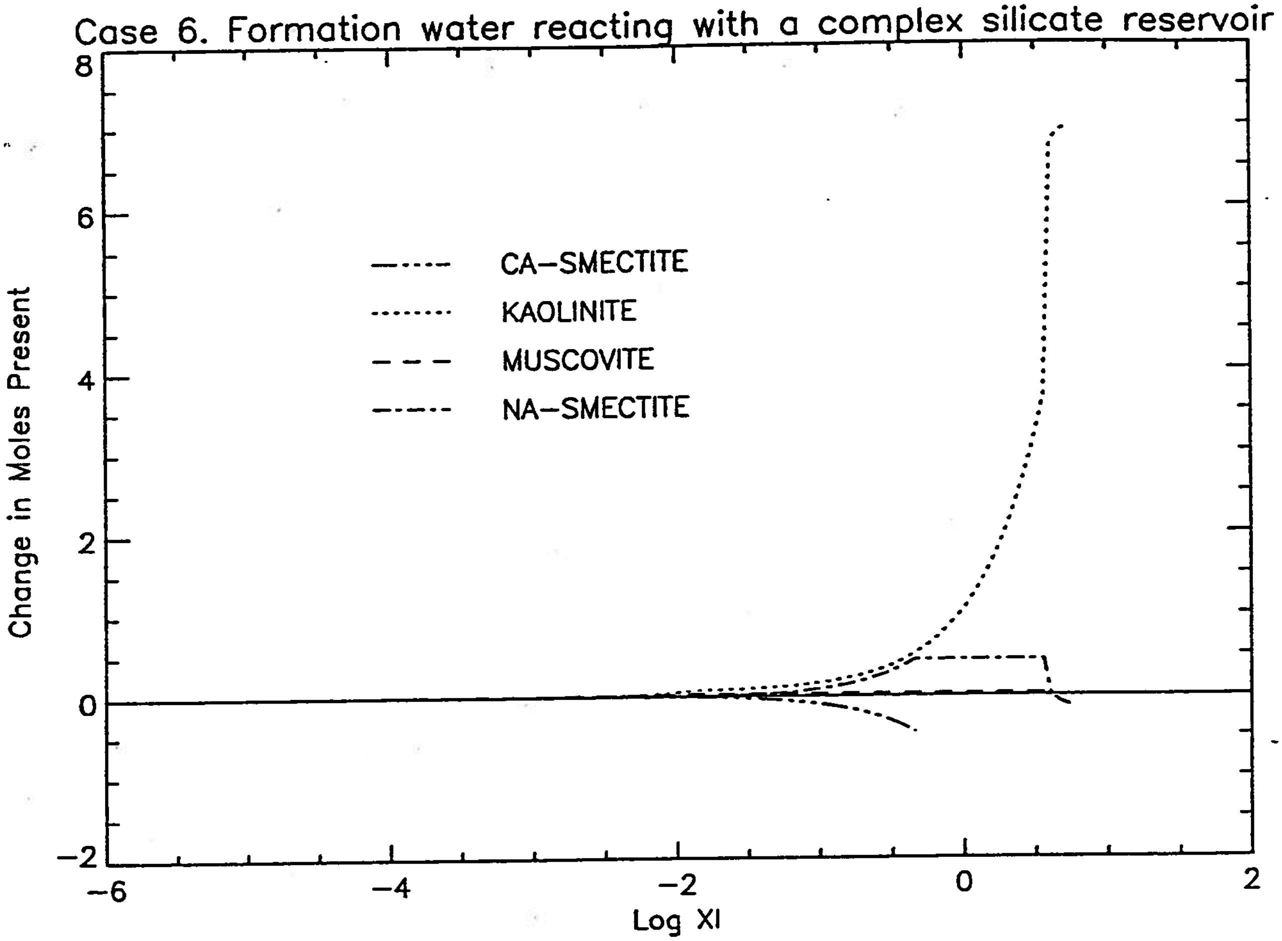

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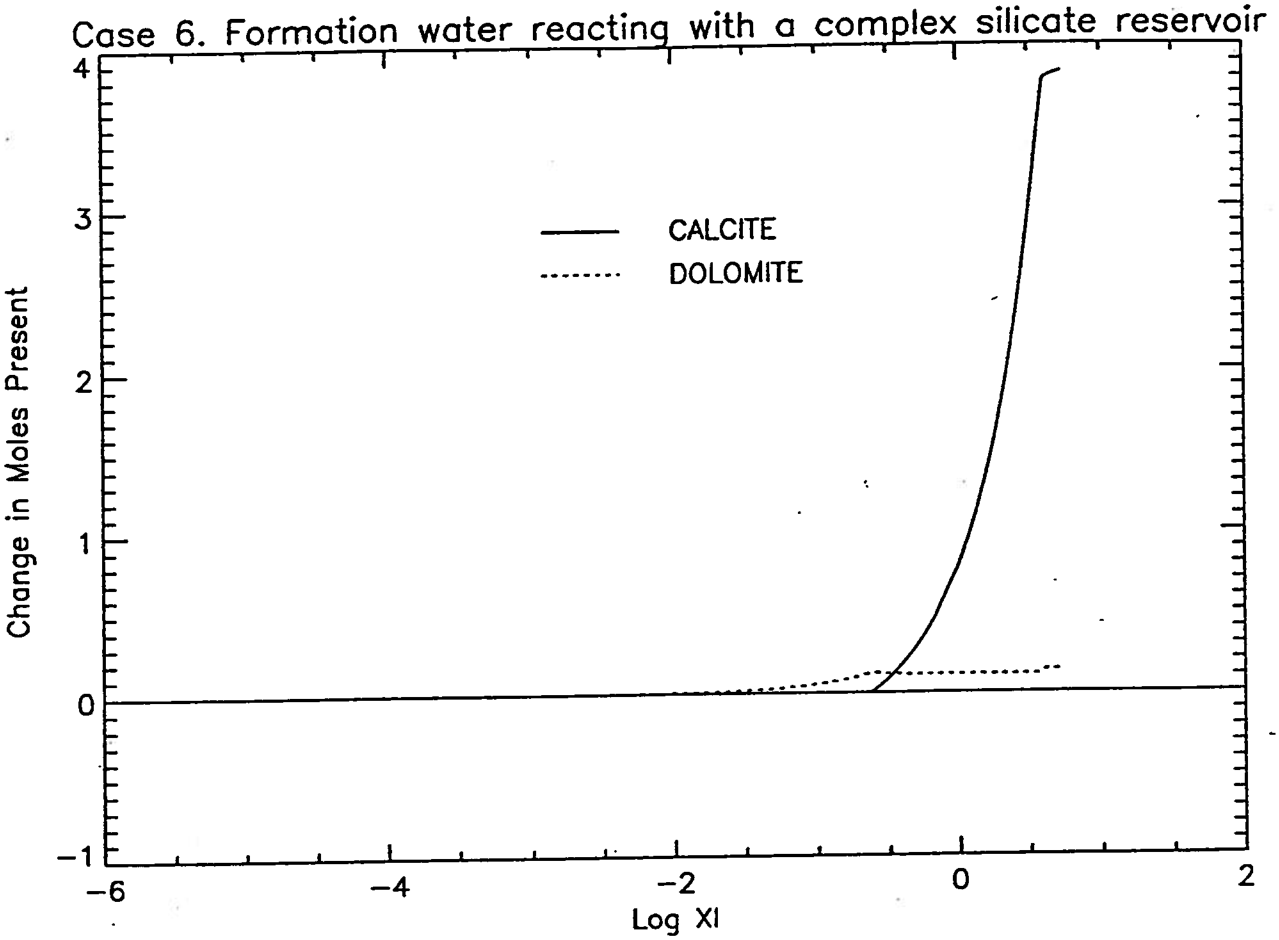

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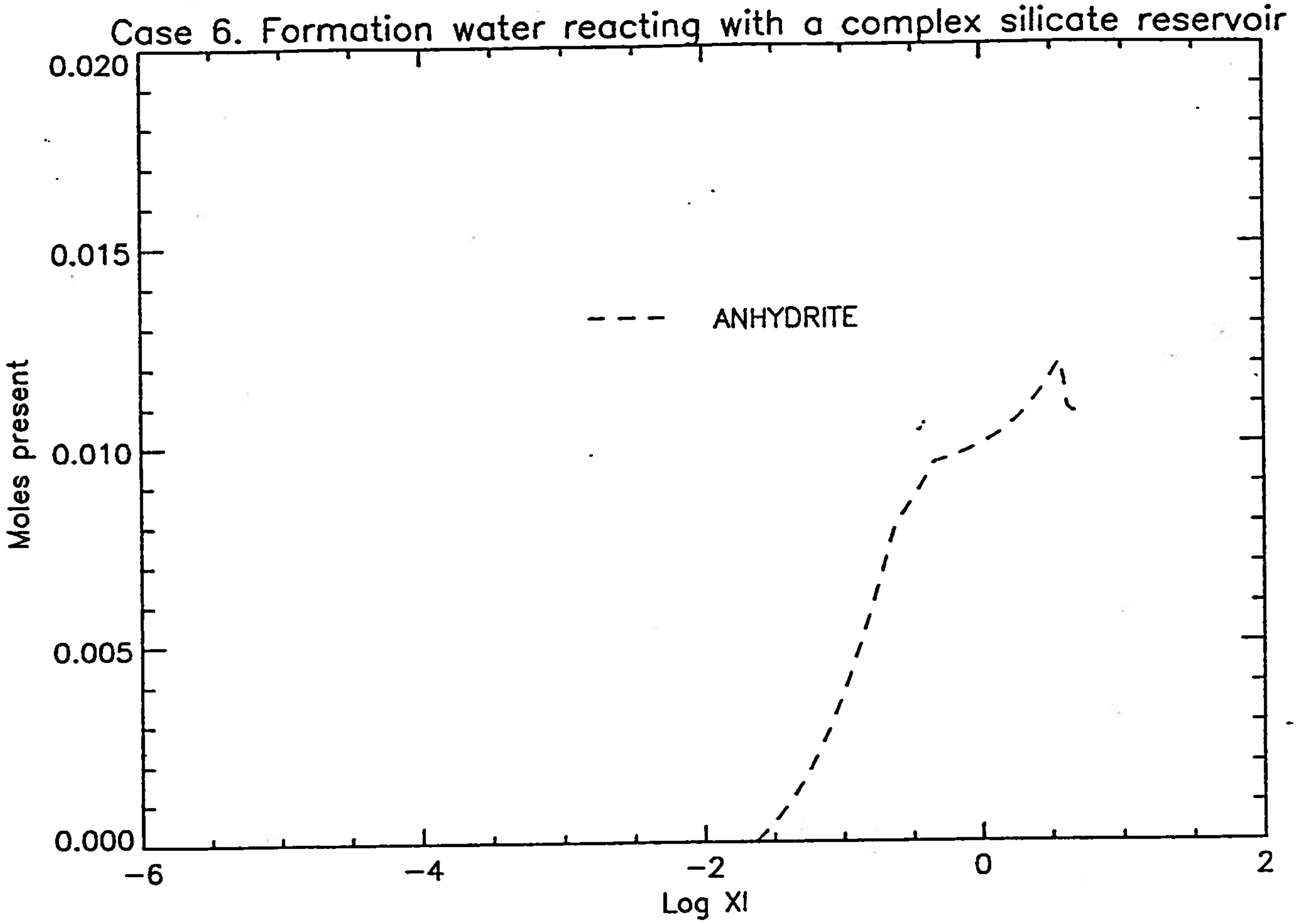

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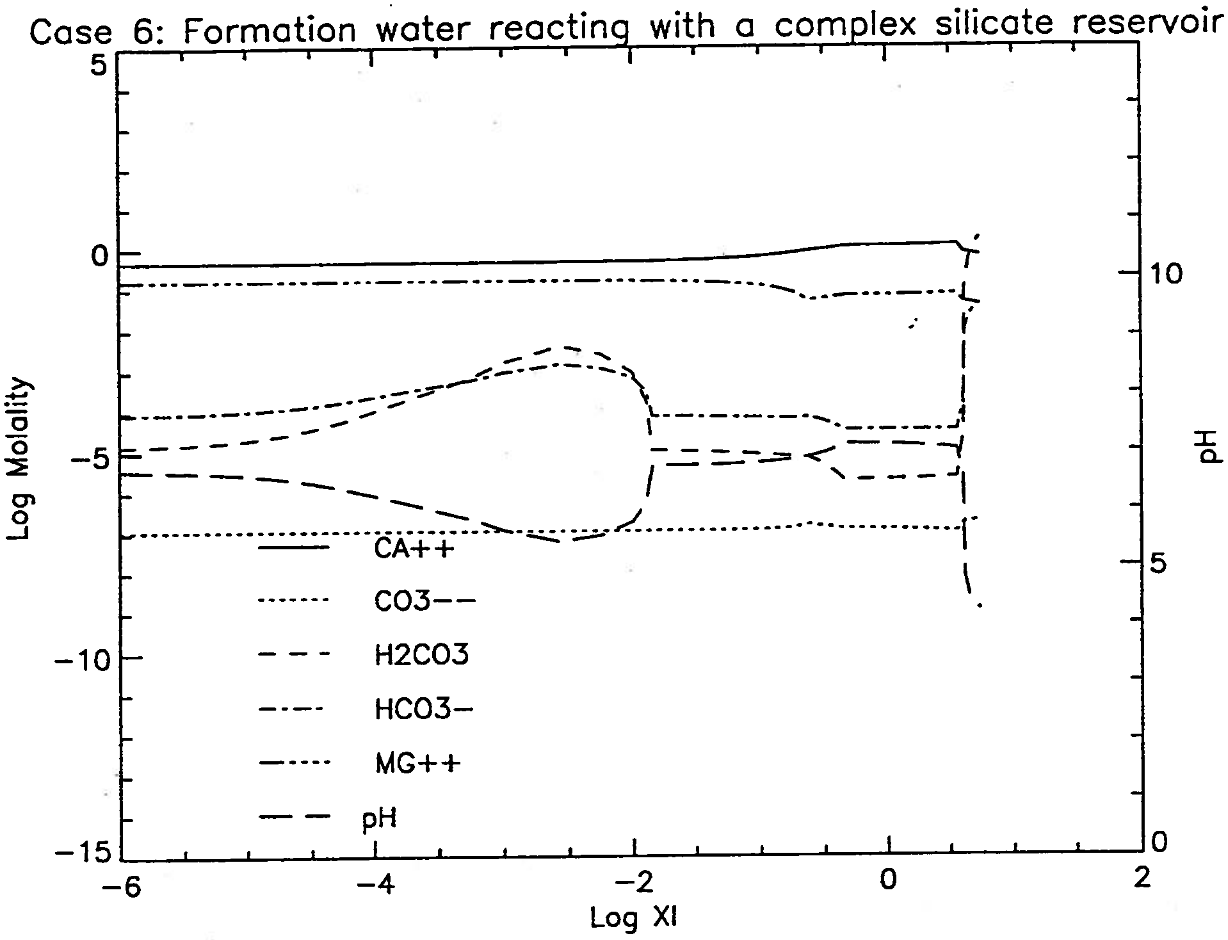

Figure 11.5.12c

APPENDIX 11.5.b

Paper Presented at IEA Conference "Carbon Dioxide Disposal"

- To appear in the Proceedings of the IEA Carbon Dioxide Disposal Symposium at Oxford, England, 29-31 March, 1993.

AQUIFER DISPOSAL OF CO_2-RICH GASES: REACTION DESIGN FOR ADDED CAPACITY

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ABSTRACT

Aquifer disposal of CO_2 is being investigated in a region between the Genesee and Sundance coal-fired power stations, west of Edmonton, Alberta, Canada. This study considers the changes to the mineralogy and water chemistry of both brackish and briney waters in carbonate and siliciclastic aquifers in this area as a result of the injection of CO_2. The conclusions are general and may be applied to any aquifer.

Brines absorb less CO_2 due to the salting out effect. The reactions between CO_2, water and aquifer solids in the carbonate aquifers can largely be described in two steps: dissolution of calcite and adsorption of dissolved calcium on clays. The dissolving CO_2 is neutralized to form bicarbonate ion due to the buffering action of the carbonate dissolution while the effect of ion exchange is to minimize the amount of dissolved calcium. In siliciclastic aquifers, the dissolving CO_2 is neutralized by reactions between basic aluminosilicate minerals (i.e. feldspars) and the resulting, more acid reaction products (i.e. kaolinite). Large amounts of carbonate minerals can precipitate during these reactions. The additional capture capacity of CO_2 due to this water-rock interaction has been found to be significant compared to that captured by simple solution of CO_2 in water. Reaction of aqueous CO_2 with calcium and magnesium bearing *basic* minerals in a siliciclastic aquifer can substantially increase the capacity of the aquifer for CO_2 disposal as compared to other aquifer mineralogies.

KEYWORDS

Carbon dioxide; disposal; greenhouse gases; aquifers; water-rock reactions; mineral sinks.

INTRODUCTION

There is currently considerable interest in using geological structures (salt domes, brines, coal beds, oil and gas reservoirs, or aquifers), the deep ocean or enhanced oil recovery as sinks for waste gas (particularly CO_2) disposal. In the short term, enhanced recovery projects can utilize CO_2 if these projects are near the CO_2 source. However in the longer term, deep aquifers appear to offer the best promise for accepting large quantities of waste gases. Their global distribution and their large *disposal volume* are appealing for disposal of waste fluids or gases, particularly from point emission sources (Koide *et al*, 1992; van der Meer, 1992). Carbon dioxide is an ideal candidate for aquifer disposal because of its high density and high solubility in water at the relatively high pressures which may be imposed in aquifers.

Geological CO_2 sinks, depending upon the time scale, may be classified as reactive or inert. Clearly, reactive sinks are the most effective for permanent long term disposal. Injection into aquifers and the subsequent dissolution into the water increases the reactivity of CO_2 considerably. In addition, flow through porous media in the crust promotes natural mixing and exposure of the dissolved CO_2 to additional grain surfaces where reactions can take place.

In this paper, the primary focus is on the generic documentation of the enhancement of CO_2 capture by reactive sinks through water-rock interaction, and builds from Dunsmore's (1992) suggestions for the use of calcium and magnesium brines. We distinguish three scenarios in the use of aquifers for the disposal of CO_2: (1) The solution of CO_2 into a formation fluid in the absence of formation mineralogy; (2) The solution of CO_2 and reaction with the minerals present in a carbonate aquifer; (3) The solution of CO_2 and reaction with the minerals in a siliciclastic aquifer. These reaction scenarios are based on aquifers close to two coal fired power plants.

AREA CHOSEN FOR STUDY

A region west of Edmonton, Alberta, Canada between the Sundance and Genesee power plants, covering a few townships (Township 49-52, Range 3-5, W5Mer) was selected as a desirable site for CO_2 disposal. Based on the general stratigraphy in the sedimentary strata in this area of the Alberta Basin (Porter *et al.*, 1982) regional siliciclastic and carbonate aquifers were identified at depths between 1400 and 2000 m. These aquifers are deep enough to be part of regional flow systems, isolated from the surface by extensive regional aquitards, yet relatively shallow in order to minimize drilling costs. The aquifers selected for evaluating CO_2 disposal are the carbonate Wabamun (Devonian) and the sandstone Lower Mannville (Cretaceous) Formations. Both aquifers have average permeabilities, porosities and thicknesses in the range of 2 md, 10% and 100 meters respectively. Based on these aquifer depths, an injection pressure of CO_2 in the order of 15MPa must be used to inject the CO_2. At these pressures, CO_2 would be injected in a liquid or supercritical state.

FORMATION WATER CHEMISTRY AND WATER-ROCK RATIO

Formation water analyses and cored intervals from the 754 wells within the area were extracted from the AGSWDB (Alberta Geological Survey well database). The formation water analyses were culled mechanically and then manually screened, resulting in 135 representative analyses from both carbonate and clastic stratigraphic units. From this dataset, two waters (brackish and a brine) were chosen as the basis for the modelling, representing extremes in TDS (i.e. approximately 4,000 versus 100,000 ppm). Sodium, potassium, calcium, magnesium and chloride are all more than an order of magnitude higher in the brine while sulphate is three times higher and bicarbonate is actually lower. The actual composition chosen for modelling depended on corrections applied to bring the formation water into equilibrium with the formation using the computer code SOLMINEQ.88 (Kharaka *et al.*, 1988; Perkins *et al.*, 1990) and simplification of the formation water chemistry pertinent to the end-member mineralogy being modeled.

The water-rock ratio in the aquifer is calculated from the porosity. Using an average porosity of 10% and an average rock density of 2.5, there are approximately 22,000 grams of rock per 1000 grams of water. Even if the porosity is doubled to 20%, the weight of rock would only be reduced to 10,000 grams. For the former case, the presence of 5 wt% of a mineral phase would account for 1000 grams of that phase being contacted by 1000 grams of water.

MODELLING OF WATER-ROCK REACTIONS

Modelling of water-rock reactions was carried out at an aquifer temperature of 25°C on stoichiometric end-member mineralogies (i.e. quartz and pure Na-, K-, Ca-, Mg- minerals) using the mass transfer geochemical computer code PATH.ubc (Perkins, 1980) and GeoCalc (Brown *et al.*, 1989). PATH.ubc calculates the path of water-rock reaction for a given set of reactants as a function of the progress variable, 'XI' which is proportional to time. As 'XI' progresses, the reactants dissolve into the formation water, resulting in a different formation water composition. The change in formation water composition may be buffered by the precipitation (or dissolution) of the equilibrium phases or by the formation of new equilibrium phases. Often an equilibrium phase is formed but later completely reacts out, and none is left in the system. PATH.ubc terminates when equilibrium has been achieved with all of the reactant phase(s) and/or when all of the reactant phase(s) have reacted out. Final equilibrium with the injected CO_2 is defined as when the partial pressure of CO_2 in equilibrium with the formation fluid has reached 15 MPa. This value was chosen as it is representative of the pressure of liquid CO_2 necessary for injection into the selected aquifers.

CO_2 SOLUBILITY IN BRACKISH WATER OR IN BRINE

If carbon dioxide is dissolved into either a brine water (i.e. TDS is greater than 100,000 mg/l) or brackish water (i.e. TDS lies between 1000 and 10,000 mg/l) with no formation minerals present, no new minerals are precipitated. The water becomes more acidic and the amount of dissolved carbon dioxide is only a function of pressure and of fluid composition. A salting out effect occurs as the water becomes more concentrated. The basis for these results is shown through the following model simulations.

CO_2 was numerically dissolved stepwise into the brackish formation water of ionic strength 0.063 at 25°C. Fig. 1, curve a, shows the rise in CO_2 pressure as increments of CO_2 are added. A CO_2 pressure of 15MPa was reached after 4 moles of CO_2 had been added to each 1000 grams of water.

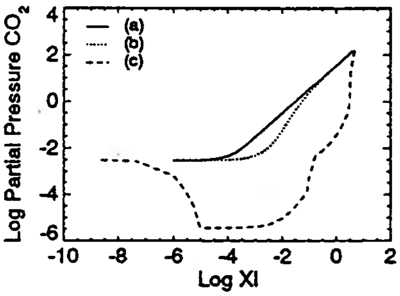

Fig. 1: Buildup of the partial pressure of CO_2 in bars as a function of time ('XI'): (a) in brackish formation water; (b) in brackish formation water in a calcite-dolomite aquifer with ion exchange; (c) in brackish formation water in an albitic (i.e. Na-rich) siliciclastic aquifer.

In contrast, the total CO_2 added to reach a CO_2 pressure of 15MPa is approximately 2 moles per 1000 grams of water for the brine formation water (ionic strength 4.00), just half of the amount added to the brackish formation water. This *salting out effect* is due to the increasing importance of hydration with salt content. As the ionic strength of the formation water increases to that of a brine, the activity coefficient of H_2CO_3 increases from 1 to 2. Obviously to maximize CO_2 solubility, dilute formation waters are favoured.

CO_2 UPTAKE IN CARBONATE AQUIFERS

If carbon dioxide is dissolved in a fluid in equilibrium with a carbonate formation (the formation mineralogy is comprised of calcite and/or dolomite, possibly with minor amounts of quartz present), the total amount of carbon dioxide dissolved into the fluid is greater than the previous case, but no new minerals are precipitated. In fact, the formation carbonate minerals dissolve into the fluid and partially neutralize the acid created by the addition of the carbon dioxide. The dominate reaction for calcite can be written as:

$$CO_2 + H_2O + \text{Calcite} = Ca^{++}\ (\text{ion}) + 2\ HCO_3^-\ (\text{ion})$$

Two aquifer mineralogies were chosen to model this reaction: a pure dolomite-calcite aquifer and a dolomite-calcite-quartz aquifer. Both were reacted with the brackish formation water. The curves for the pure dolomite-calcite aquifer are almost identical to those of the pure formation water example (compare curve a, Fig. 1 to Fig. 2a) because only a small amount of calcite and dolomite have dissolved by the time equilibrium is reached (0.004 moles of dolomite and 0.05 moles of calcite; see Fig. 2c). This causes the concentration of bicarbonate ion to substantially increase (Fig. 2b) which results in an increase of approximately 1.5% or 0.06 moles of CO_2 gas dissolved (Fig. 2d) when compared to the pure formation water case.

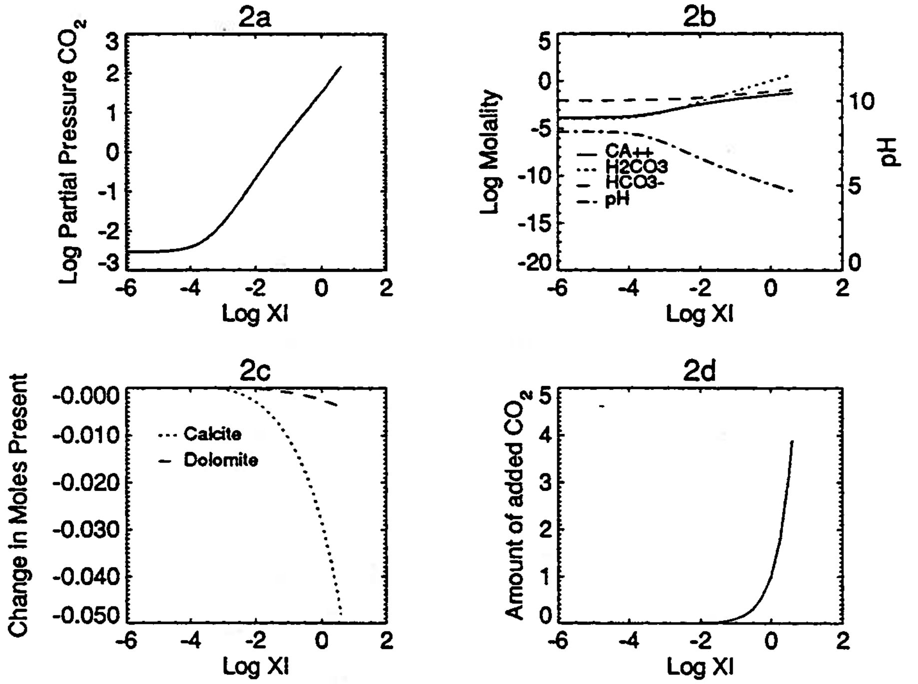

Fig. 2: Reaction of brackish formation water with a calcite-dolomite carbonate aquifer as CO_2 is injected into the aquifer; plotted as a function of time ('XI'): (a) buildup of the partial pressure of CO_2 in bars; (b) change in the molality of the aqueous species; (c) change in the moles of mineral reactants; (d) molar amount of CO_2 injected into the aquifer.

The amount of additional CO_2 which can be added to a calcite-dolomite-quartz aquifer is identical to the calcite-dolomite aquifer. The quartz dissolves to saturation and is unaffected by the addition of the CO_2. No new phases are formed and the same amounts of calcite and dolomite are dissolved. In the case of a calcium-rich brine, the same conclusions hold except the amount of CO_2 and calcite dissolved is less when compared to the brackish formation water. Consequently, depending upon the specific formation water chemistry, reaction of a carbonate formation can result in an increase of dissolved carbon dioxide by 1 to 4%. If clays are present with a high cation exchange capacity, they will buffer the calcium and magnesium in the formation water, allowing more calcite and dolomite to dissolve. This is shown by the depression of the CO_2 - 'XI' curve (curve b, Fig. 1). This effect is most pronounced for low ionic strength formation waters where the CO_2 capture can be increased to 2 to 8%.

CO_2 UPTAKE IN SILICICLASTIC AQUIFERS

Siliciclastic aquifers containing basic silicate minerals (i.e anorthitic feldspar, chlorite, albitic feldspar and potassium feldspar) can absorb more CO_2 (see Gunter and Bird, 1988, for an explanation) than other aquifers through a complex set of water-rock reactions. These reactions can be summarized in a general sense by the reaction of feldspar and clay silicate minerals with CO_2:

$$\text{Feldspars + Clays + } CO_2 \text{ --> Kaolinite + Calcite + Dolomite + Quartz}$$

The reactant clays are comprised of both illites, chlorites and smectites. The final ratio and the respective amounts of calcite and dolomite is dependent upon the initial formation mineralogy and formation water composition. The more feldspars and clays initially present, the more carbonate minerals produced as reaction products and the more carbon dioxide trapped in the formation. Generally, we have chosen to take a simple approach to modelling the effect of the four end-member basic silicates on CO_2 uptake. We have represented the aquifer solids as a three phase mixture; excess quartz (representing the dominant phase in the aquifer solids) and 1000 grams (i.e. 5 wt%) of each of the basic end-member silicate (i.e. anorthite, chlorite, albite and potassium feldspar) and other clays (note that we used muscovite as a proxy for the clay mineral illite).

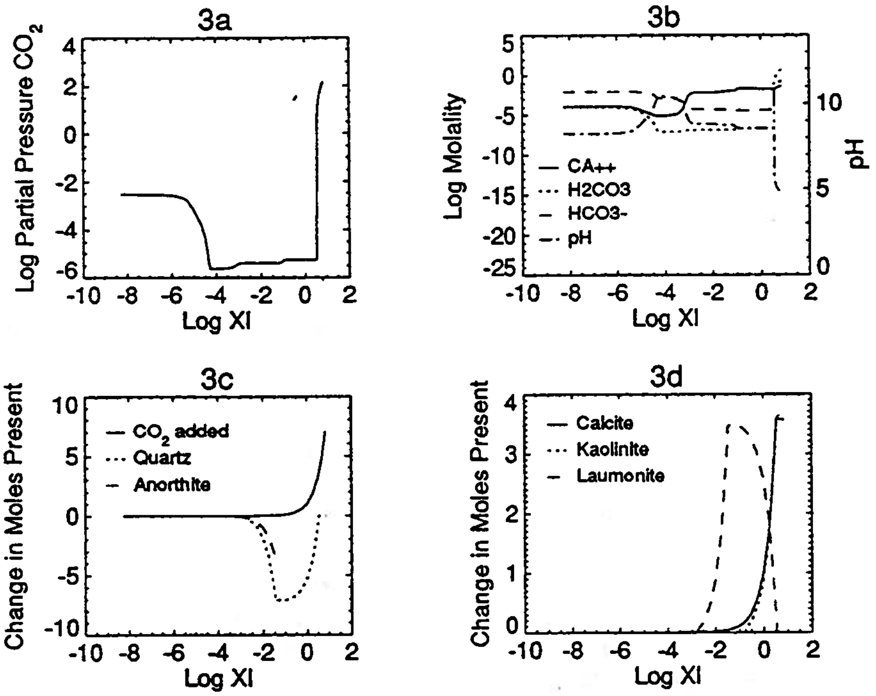

Fig. 3: Reaction of brackish formation water with an anorthite- muscovite-quartz siliciclastic aquifer as CO_2 is injected into the aquifer; plotted as a function of time ('XI'): (a) buildup of the partial pressure of CO_2 in bars; (b) change in the molality of the aqueous species; (c) change in the moles of the initial formation mineralogy and the amount of CO_2 injected into the aquifer; (d) change in the moles of mineral products.

To model the effects of CO_2 addition to a formation mineralogy rich in calcium, the three phase assemblage, anorthite, muscovite and quartz, was allowed to react with CO_2 in a brackish formation water. The calculated reaction paths are complex with anorthite and quartz initially reacting to form laumontite (Fig. 3c & d). Muscovite is stable and little reaction occurs. Once all of the anorthite has reacted out, the laumontite then breaks down to form kaolinite, calcite and quartz. The reaction progress can be followed by monitoring the partial pressure of CO_2 in Fig. 3a or the change in the aquifer water chemistry in Fig. 3b. The first part of the curve is similar to that for no water-rock reaction; flat. However instead of a steep rise, the CO_2 sharply drops to a flat minimum, as first the pH is buffered to more basic conditions and then as calcite precipitates. Each plateau in the minimum of the CO_2 curve marks the loss or precipitation of a new phase. The CO_2 pressure starts to rise sharply to the final imposed pressure only after all the laumontite has reacted out. At this point there is no source of calcium left to form calcite, thus allowing the level of carbonate (dissolved CO_2) in solution to increase rapidly. In addition, a small amount of calcite will dissolve as the CO_2 pressure builds up to 15 MPa. Approximately four moles of CO_2 have precipitated as calcite (Fig. 3d). The amount of CO_2 locked up in the aquifer has doubled when compared to the non-reactive or to the carbonate aquifer cases. If the mass of available anorthite had been increased, more CO_2 could have been trapped by the continued precipitation of calcite. Although not shown here, modelling the effect of temperature, a formation brine and/or a complex calcium-rich mineral assemblage support these conclusions.

The magnesium-rich siliciclastic aquifers were modelled as a mixture of clinochlore (i.e. chlorite) and quartz. The results are similar to the calcium-rich ones, except that magnesium-rich silicate minerals form and breakdown; the magnesium released finally combining with CO_2 to form magnesite. The final assemblage is quartz, magnesite and kaolinite. Over 9 moles of CO_2 have been trapped by the precipitation of magnesite. This emphasizes the earlier results that **the actual amount of CO_2 locked up by precipitation of carbonate minerals is limited only by the amount of basic calcium and magnesium silicate minerals present in the aquifer solid assemblage.**

The sodium-rich siliciclastic aquifers were modelled as a mixture of 5 wt% of albite and muscovite in the presence of excess quartz. As was observed in previous simulations, the muscovite behaved inertly. The final equilibrium assemblage is muscovite, quartz and sodium smectite. The kaolinite stability field was never reached because the large sodium build up in the formation fluid stabilized smectite. The CO_2 pressure curve (Fig. 1, curve c) rises from the minimum much earlier than for the Ca- or Mg- cases (Fig. 3a) because no carbonate phases precipitate. Final CO_2 takeup is 5 moles, of which 4.4 moles is present in the form of bicarbonate ion and 1.6 moles as dissolved CO_2. Even though the initial formation water was a brackish formation water, the buildup of the bicarbonate ion increases the ionic strength from 0.063 to 4.41. This results in a significant salting out effect for the dissolved CO_2. The observed concentration of bicarbonate is more than an order of magnitude higher than calculated for the calcium- or magnesium-rich siliciclastic aquifers. The buildup of bicarbonate cannot occur for the calcium or magnesium cases because of early saturation with calcite, magnesite and/or dolomite.

The effects of CO_2 addition to a dilute formation water in a potassium-rich siliciclastic reservoir were modelled using a formation composed of 5 wt% of each potassium feldspar and muscovite, in the presence of excess quartz. Under these conditions, the potassium feldspar reacted to form muscovite and quartz, both of which remained in equilibrium with the fluid during the addition of CO_2. The pressure of CO_2 climbed steadily similar to the carbonate aquifer case (Fig. 1, curve b) as it was not affected significantly by the mineral reactions. The potassium subsystem is by far the least reactive of all of the siliciclastic systems considered under high CO_2 pressures; the final bicarbonate ion concentration reaches only 0.6 molal. Although this is considerably higher than its calcium and magnesium counterparts, it is only a fraction of the concentrations reached by the sodium analogue simulation. Consequently, siliciclastic aquifers dominated by potassium accessory phases would not enhance the CO_2 uptake significantly above the 4 moles dissolved in the inert (mineral absent) aquifer case.

SUMMARY AND CONCLUSIONS

The modelling results indicate that brackish and dilute formation waters in aquifers can take up more CO_2 than brine formation waters; **thus brackish or dilute formation waters are favoured for CO_2 capture.** The maximum solubility of CO_2 is limited in brines due to the salting-out effect at higher ionic strengths.

The reaction of the mineralogy and formation water for a carbonate aquifer with injected CO_2 does not significantly increase the CO_2 uptake. However, if the carbonate aquifer contains significant amounts of clays with a large cation exchange capacity, the final CO_2 capture capacity will be a little greater than for a clay-absent carbonate aquifer.

The maximum amount of CO_2 can be trapped in a siliciclastic aquifer containing a brackish formation water. The amount of trapped CO_2 is dependent upon the amount of and type of basic minerals (feldspars and clays) present in the formation. Magnesium- and calcium-rich siliciclastic aquifers are favoured for neutralization and trapping of the injected CO_2 through the precipitation of calcite (calcium carbonate), dolomite (calcium magnesium carbonate) or magnesite (magnesium carbonate). The amount of CO_2 captured can be increased through formation of aqueous complexes and precipitation by more than a factor of two over solubility in a brackish formation water. The exact amount depends upon the amount of available calcium and/or magnesium in the formation minerals and the pressure of CO_2. Sodium-rich siliciclastic aquifers will absorb CO_2, neutralizing it to form bicarbonate ions and thus converting the brackish chloride formation water to a bicarbonate brine. The increase in CO_2 solubility due to formation of bicarbonate is only partially balanced by the salting out effect due to the increased ionic strength. Thus a sodium rich formation mineralogy may be favoured as a disposal site when the precipitation of carbonate minerals must be avoided. Potassium-rich siliciclastic aquifers equilibrate more rapidly than their sodium counterparts and only limited amounts of bicarbonate ion are formed. Thus CO_2 capture is not enhanced significantly for potassium-rich siliciclastic aquifers.

One concern which has not been addressed in this paper is that the most efficient capture mechanism (i.e. carbonate mineral precipitation) may reduce the permeability of the reservoir. Detailed examination of permeability changes are beyond the scope of this paper as they depend upon the permeability and the porosity of the aquifer, the amount and surface area of the reactive minerals available, the kinetics of the reactions and on the attachment sites of the mineral products. This is not the case for carbonate aquifers because only dissolution occurs. Thus the porosity and permeability must increase in these reservoirs as CO_2 is injected. The net change in porosity can be calculated for siliciclastic aquifers but not the permeability. However, in the early stage of reaction in the siliciclastic reservoirs, dissolution is the predominate mechanism. From this, we can conclude that in the near well region of a CO_2 injection well, permeability and porosity should increase. Resolution of the permeability changes in a siliciclastic reservoir can only be addressed by physical simulation using core plugs under the actual conditions of aquifer disposal; where CO_2-charged water would be flowed through an aquifer core at different rates and the permeability changes monitored as a function of time.

The reactions considered in this paper have been numerically simulated using a closed system reaction type of geochemical model in which the calculation is normalized to one liter of water. These calculations are limited because they assume a closed environment of reaction. In reality, CO_2 disposal should be modelled in the context of the hydrodynamics of a sedimentary basin. In a sedimentary basin, deep groundwater moves on the order of one centimeter to one meter a year. The basins are typically hundreds of kilometers across, so basinal water movement is measured in thousands of years. During that time, the CO_2-charged formation waters will be exposed to a much larger mass of solids than assumed for the modelling carried out here. Consequently, over periods of thousands of years, the reaction between the *basic* minerals in the aquifers will be responsible for capture of more CO_2 than predicted by our model calculations. This will limit the mobility of the CO_2 to a smaller radius than would otherwise be expected. These effects of an open system should be evaluated and included as part of any aquifer model used for assessing the long term effects of CO_2 aquifer disposal.

The CO_2 capture potential and the geochemical reactions discussed in this report are part of a preliminary engineering feasibility study to examine the fixation of CO_2 in carbonate and siliciclastic aquifers. In parallel, scoping experiments in autoclaves are being undertaken to verify the results of the numerical modelling reported here. The experiments are the subject of a separate communication. The feasibility of injection, the sustainable injection rates and the long term pressure effects on a model Alberta aquifer in the area of the Genesee and Sundance power plants have already been determined. Based on these results, preliminary designs and conceptual cost estimates to implement aquifer disposal of CO_2 are being undertaken.

ACKNOWLEDGEMENTS

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APPENDIX 11.6.1

X-Ray Diffractograms of Mineral Reactants

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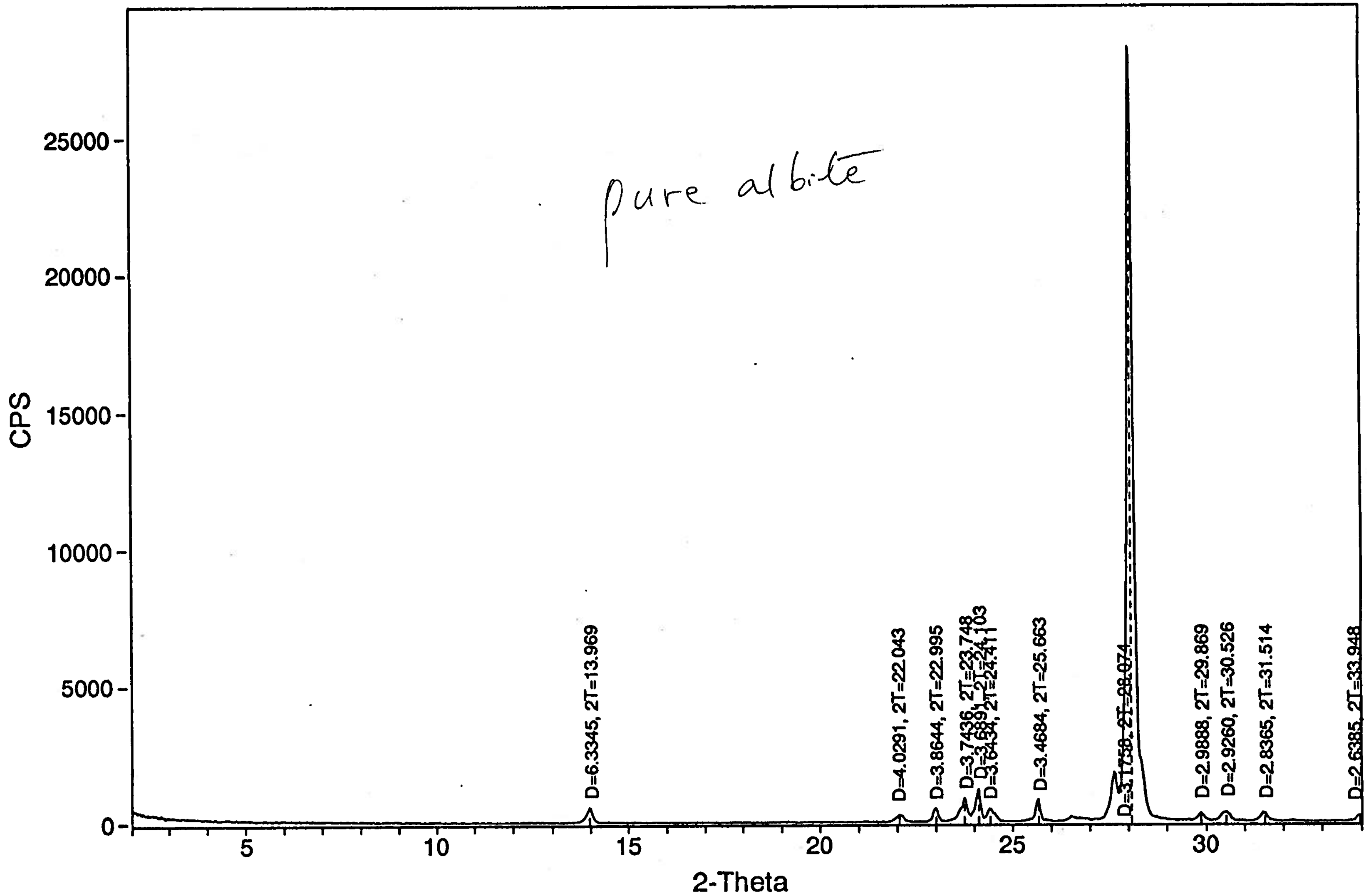

pure albite

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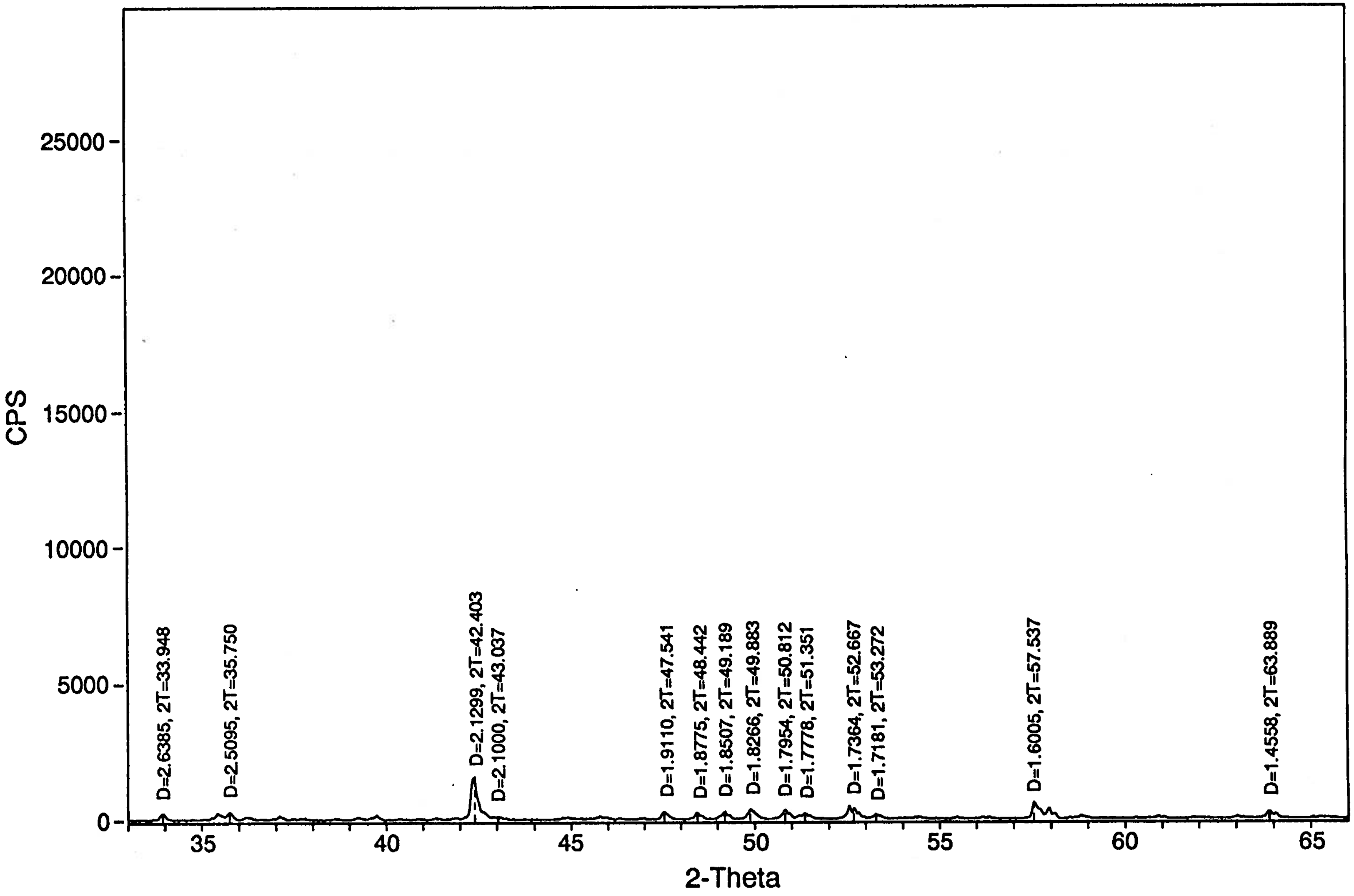

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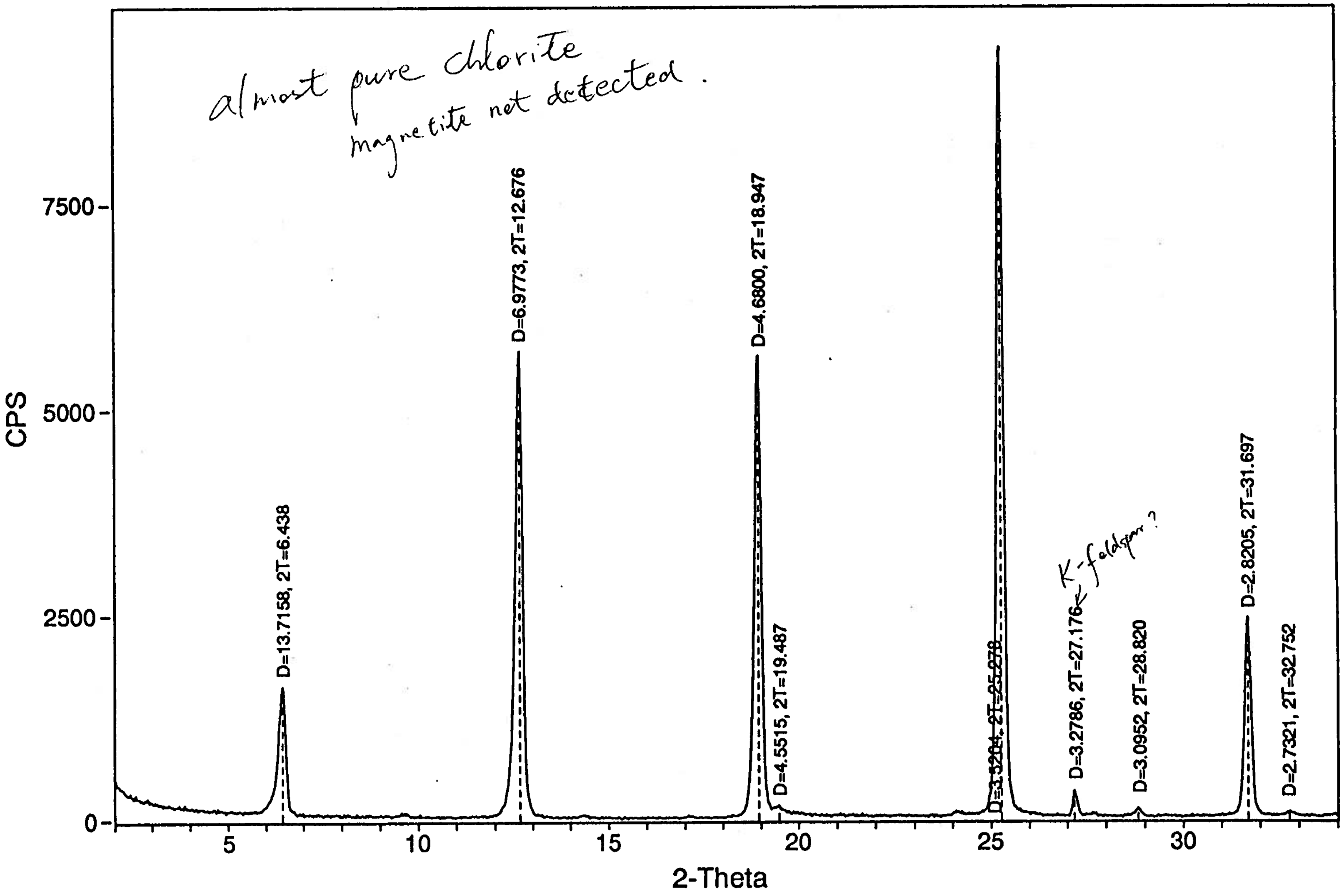
almost pure chlorite

magnetite not detected.

ID: C:\CO2\CLINO.MDI: CO2 Clinochlore

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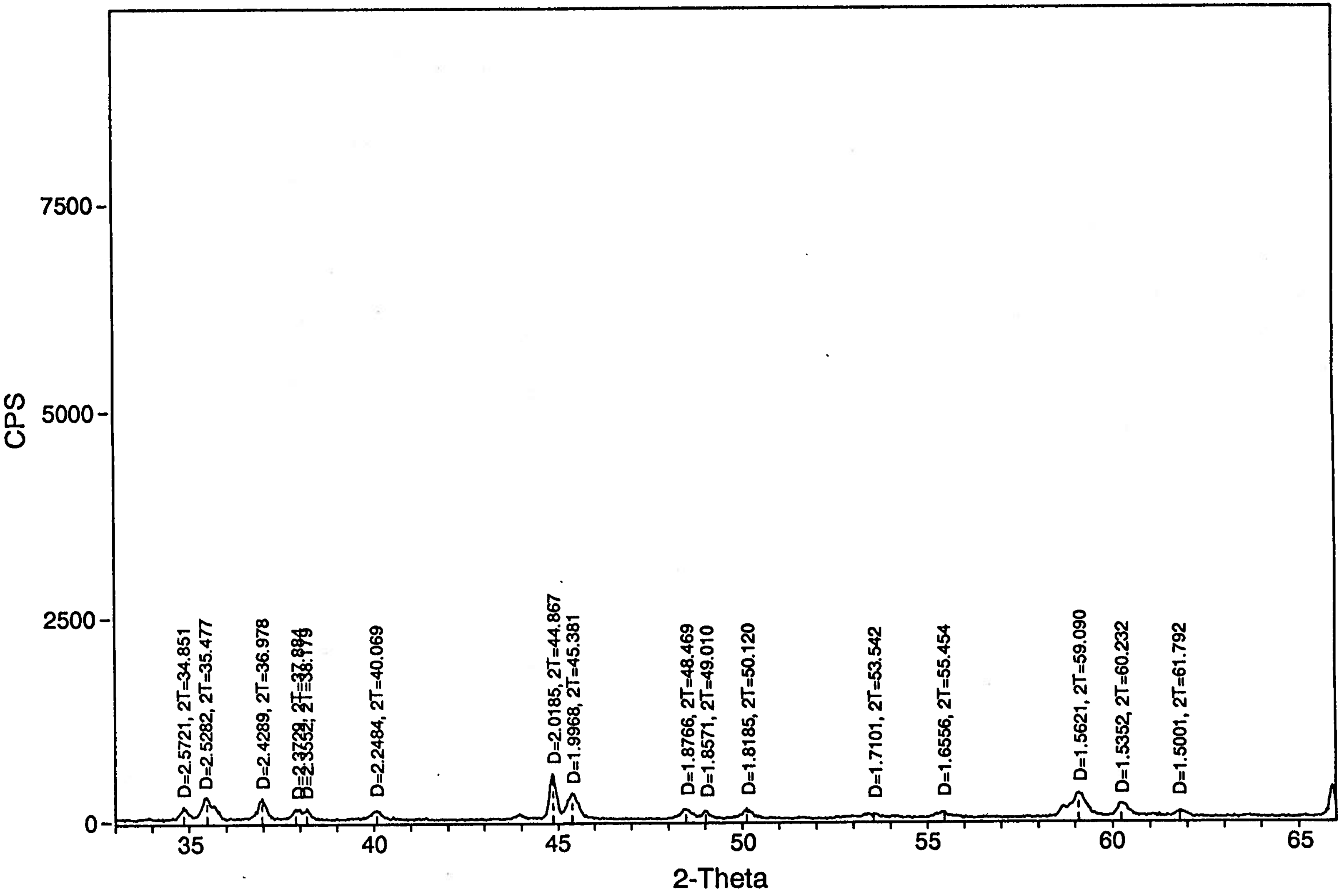

ID: C:\CO2\MICROBP.MDI: Microcline Back Pack

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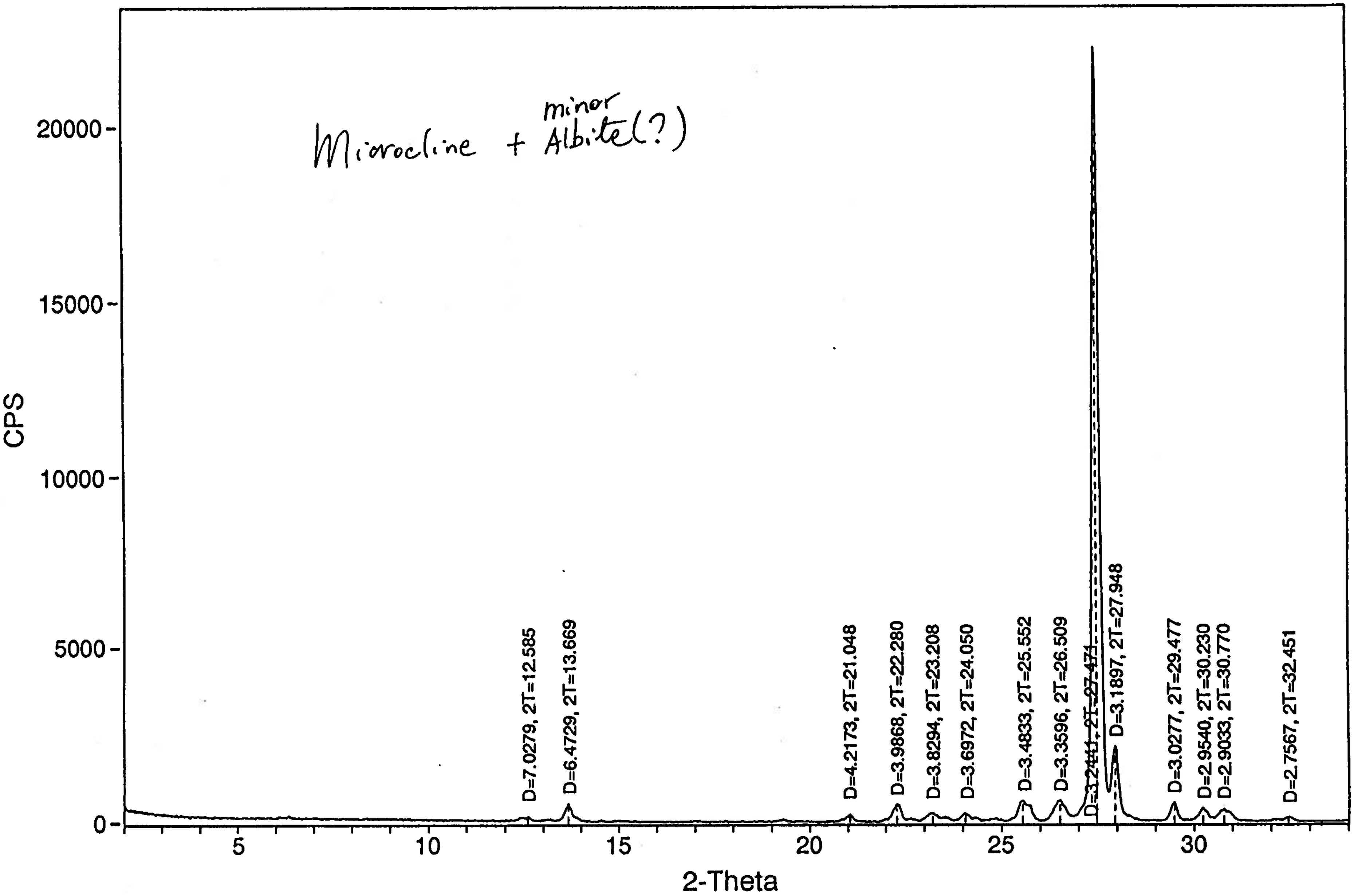

Microcline + minor Albite(?)

ID: C:\CO2\MICROBP.MDI: Microcline Back Pack

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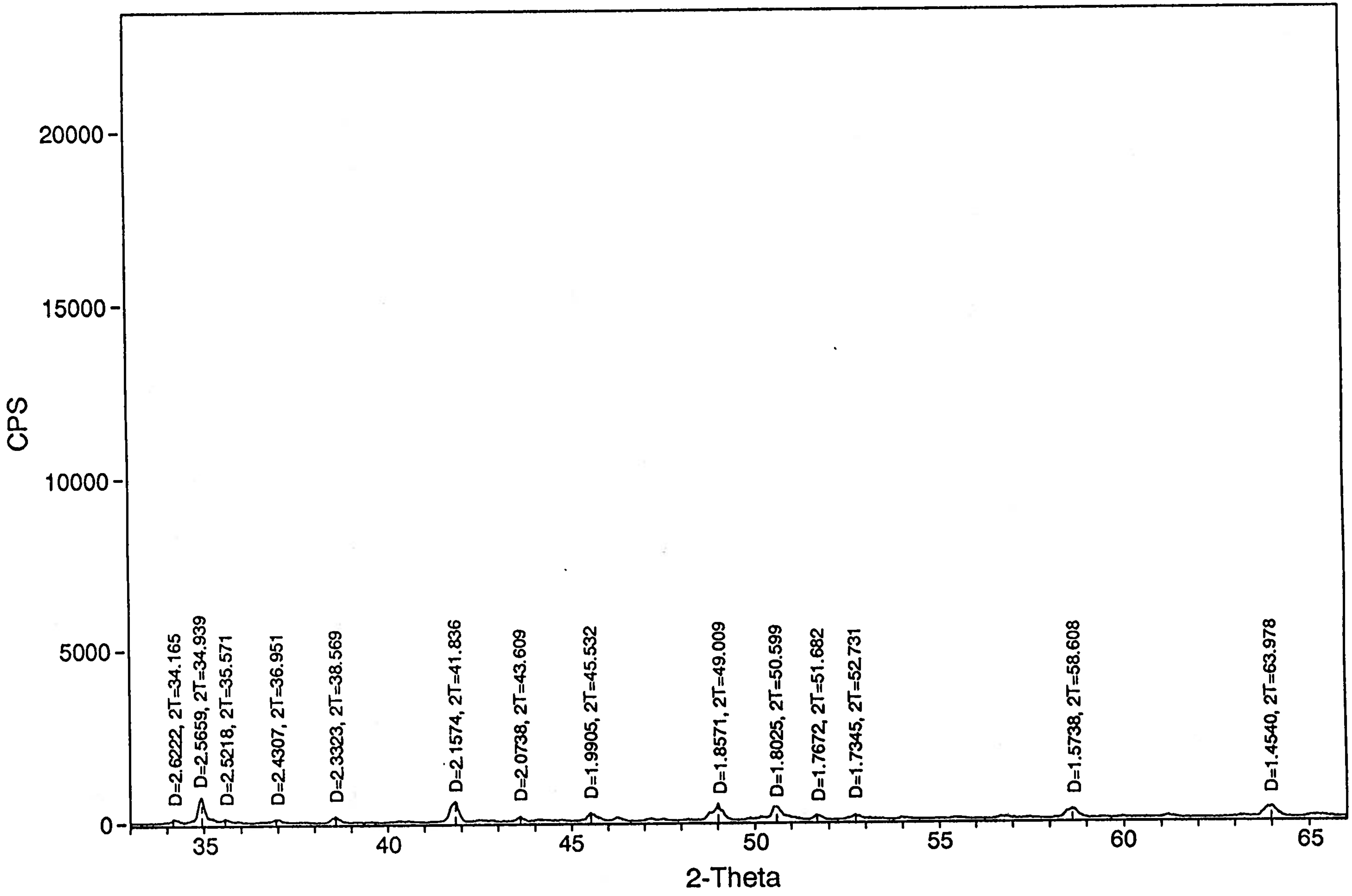

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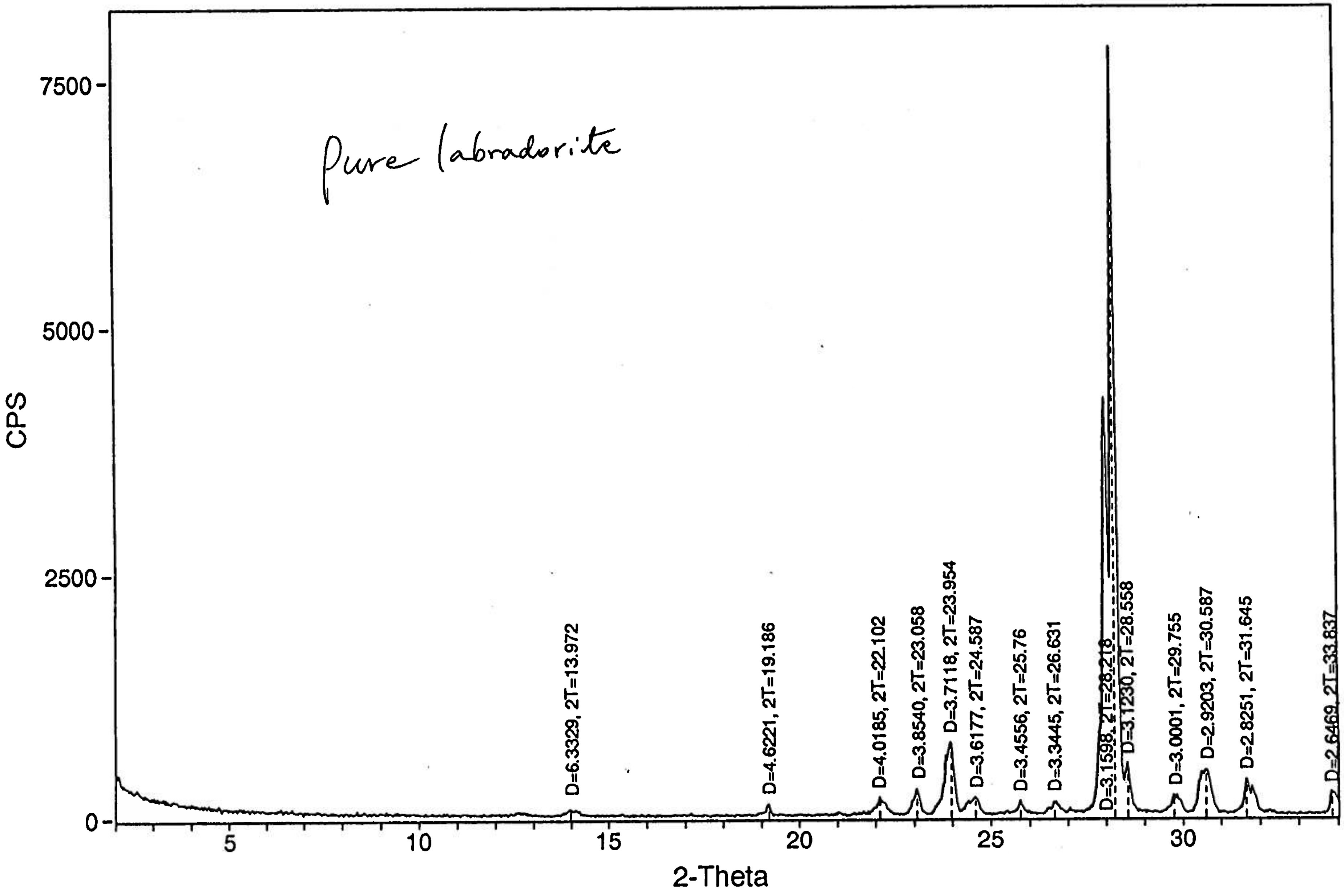

Pure labradorite

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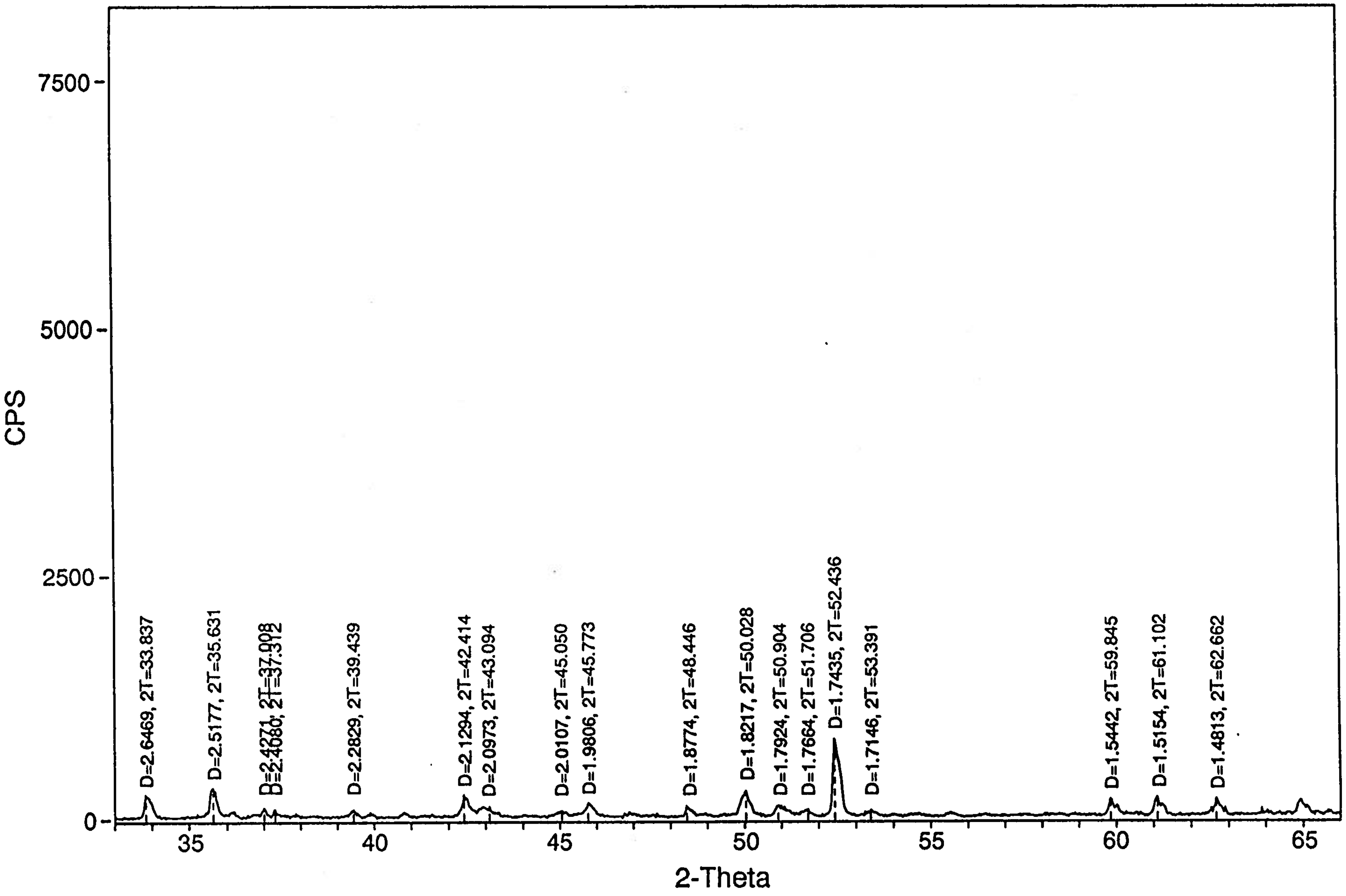

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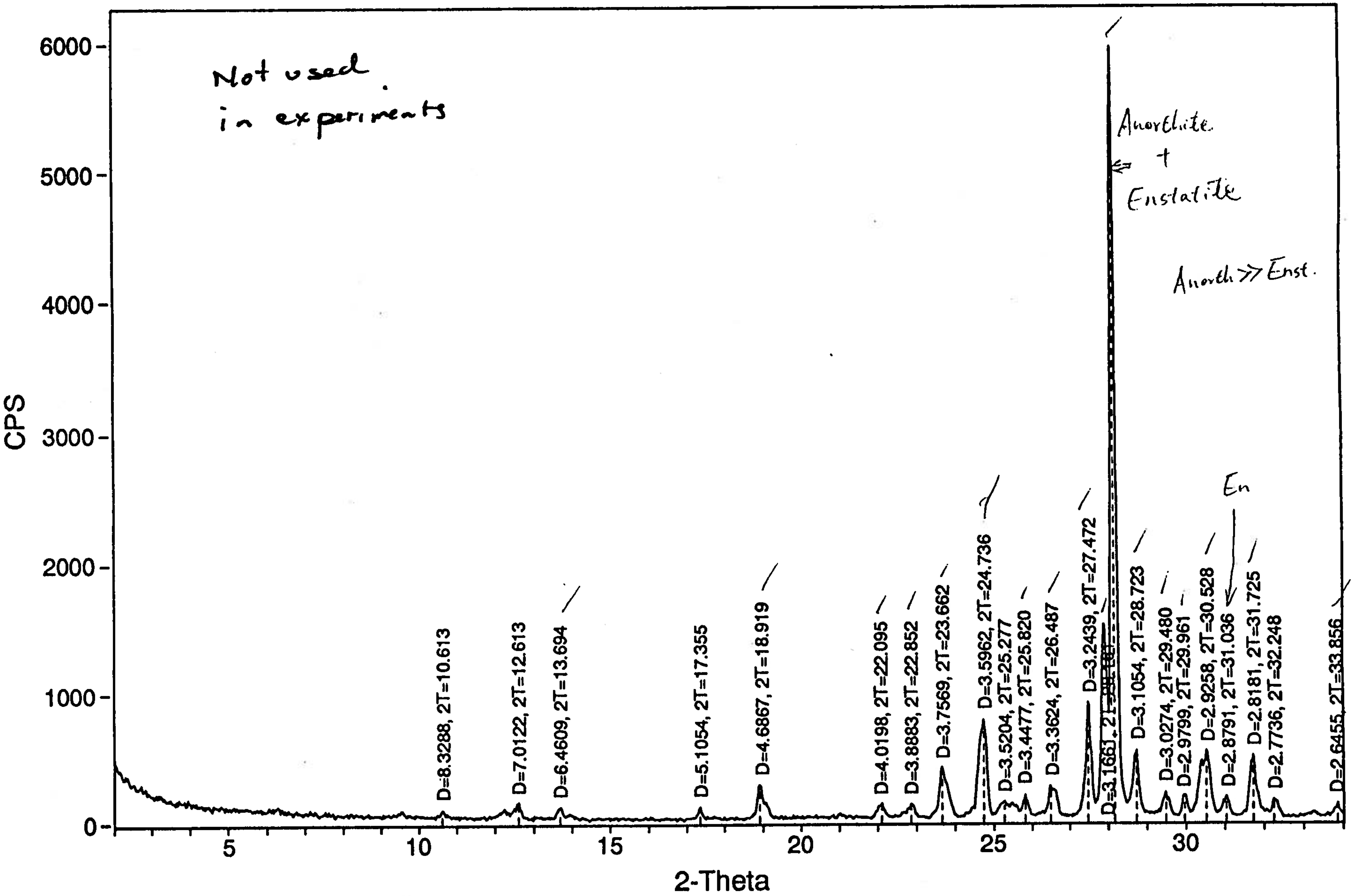

Not used in experiments.

Anorthite + Enstatite

Anorth >> Enst.

En

ID: C:\CO2\ANORTH.MDI: CO2 Anorthite Back Pack

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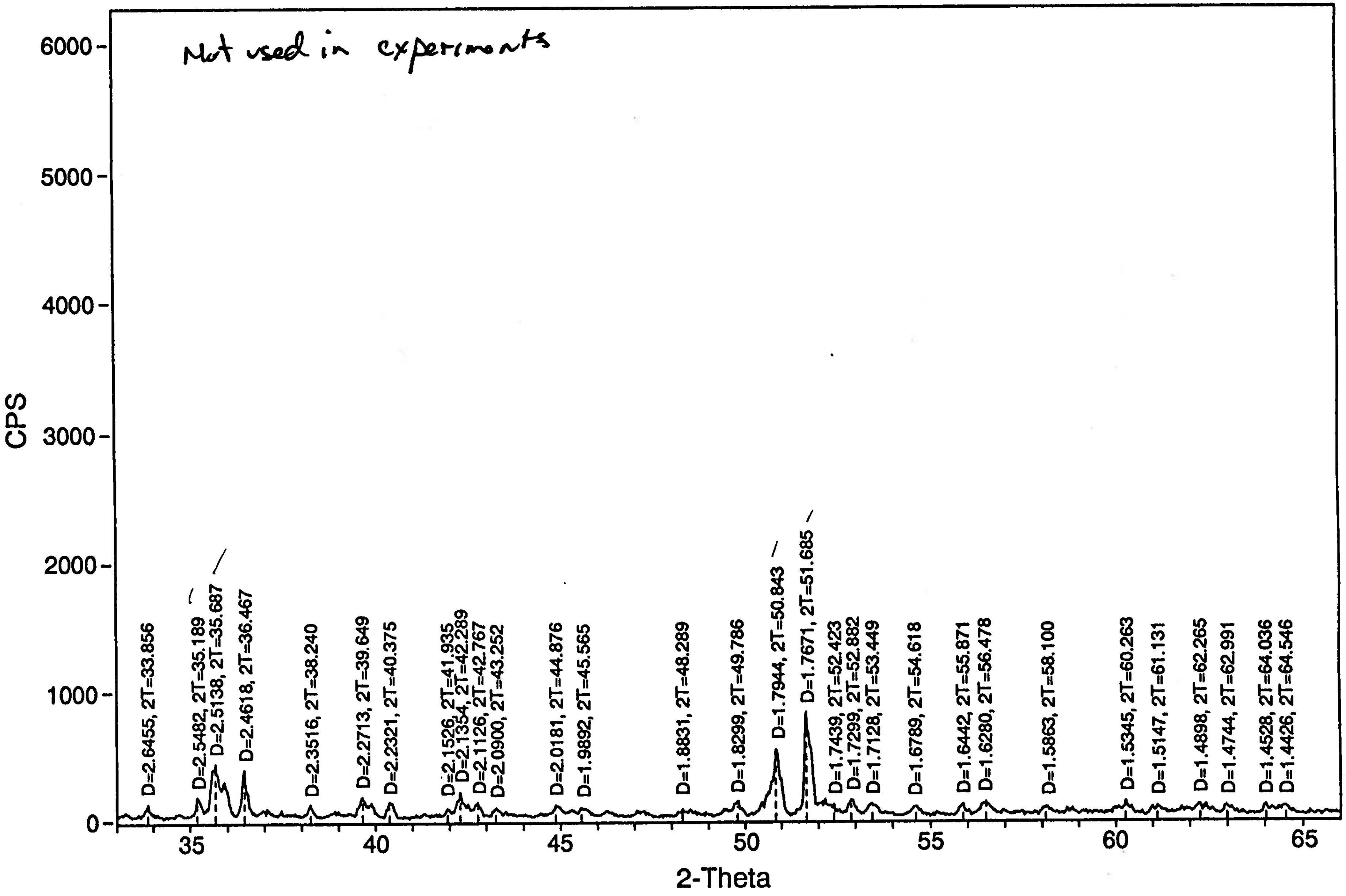

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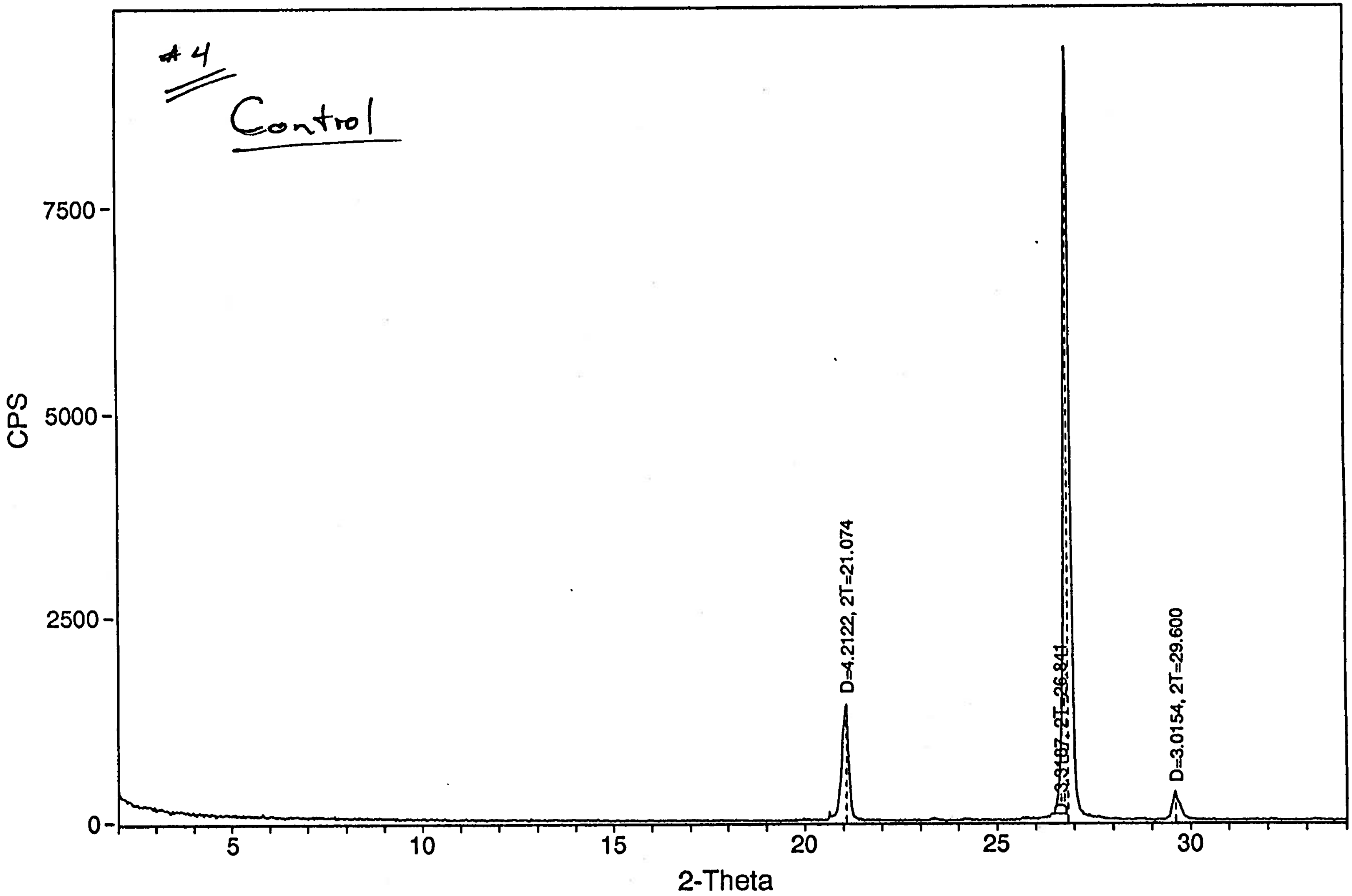

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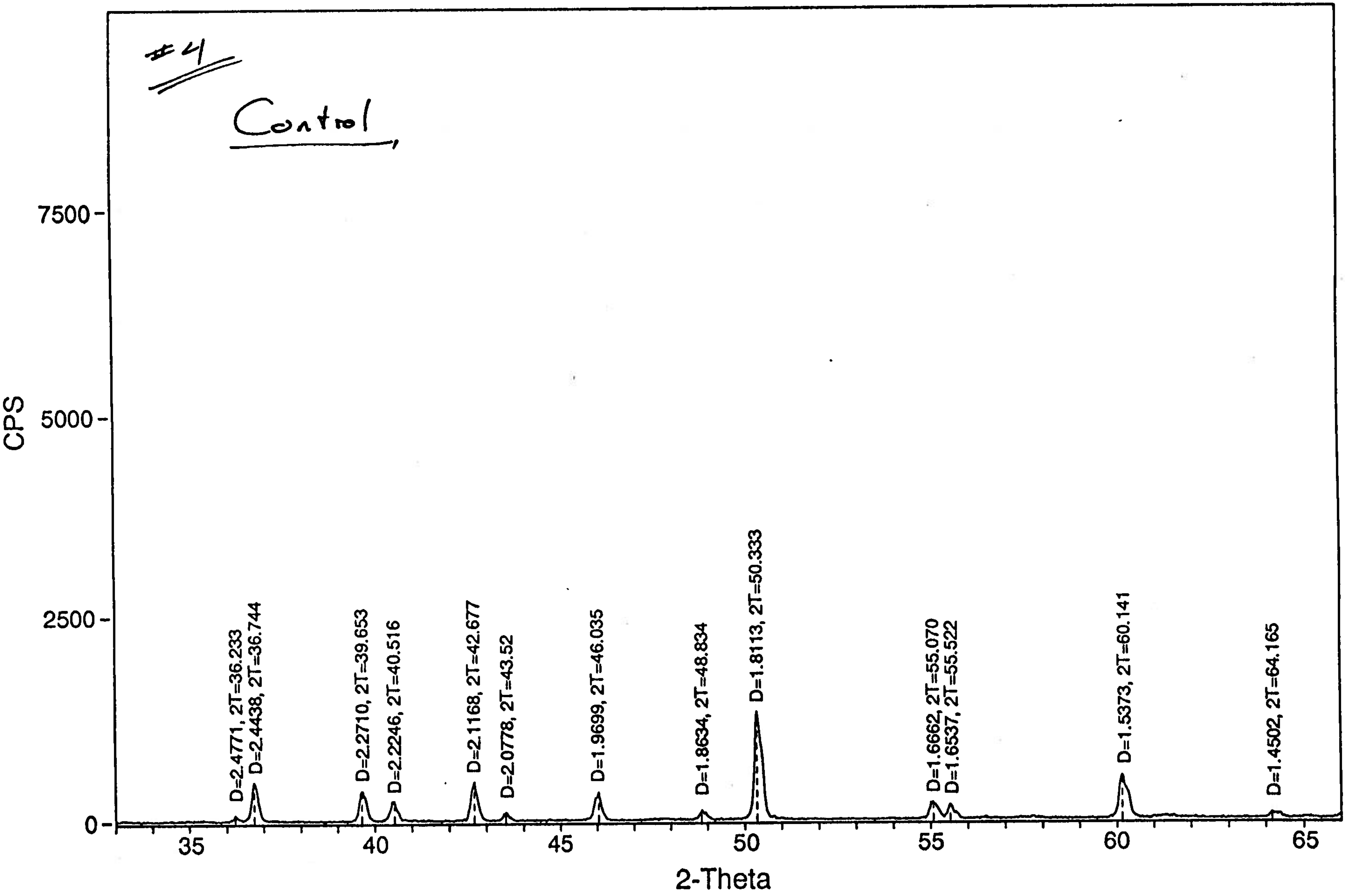
#4

Control

APPENDIX 11.6.2

X-Ray Diffractograms of Reaction Products

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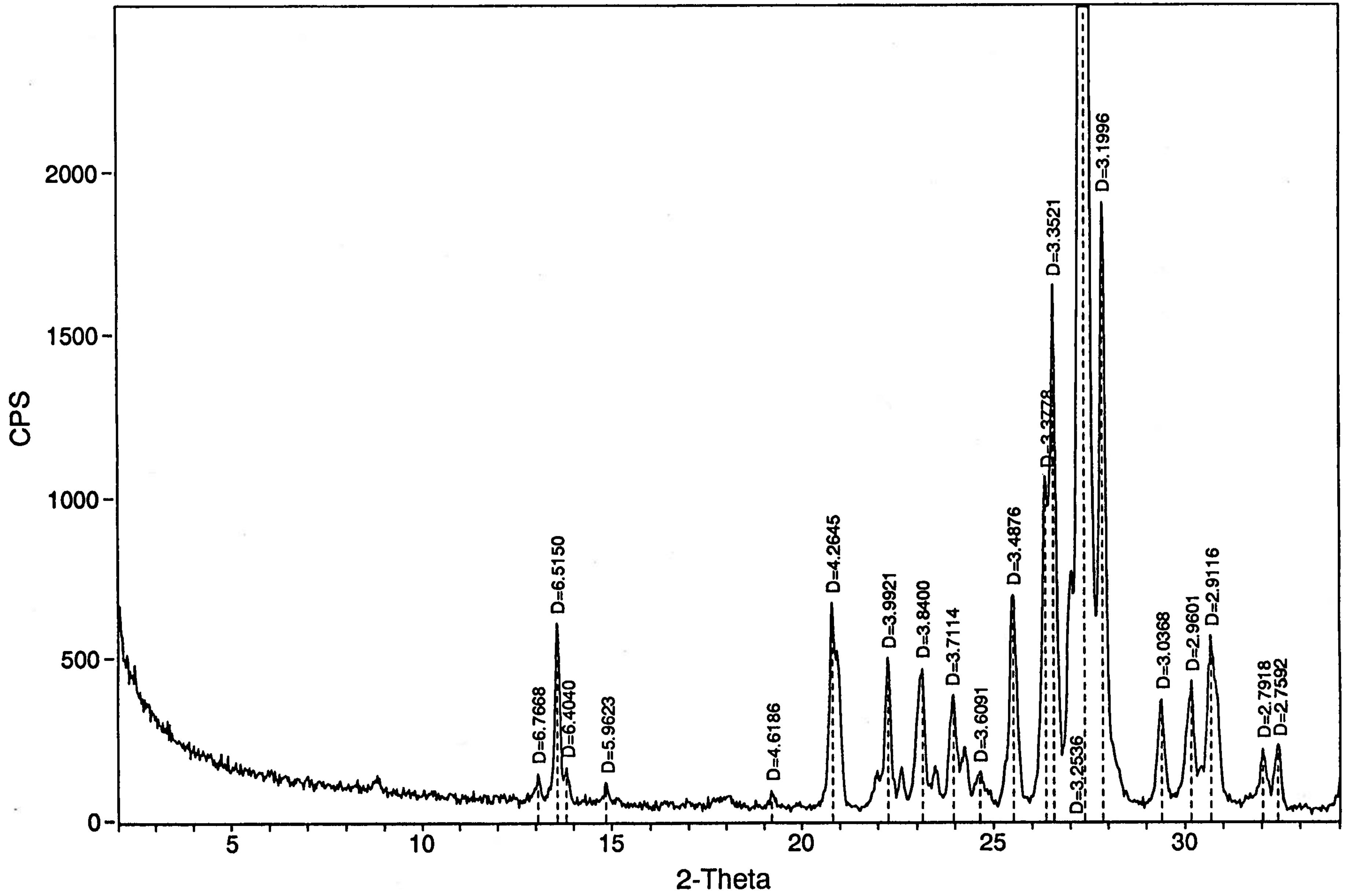
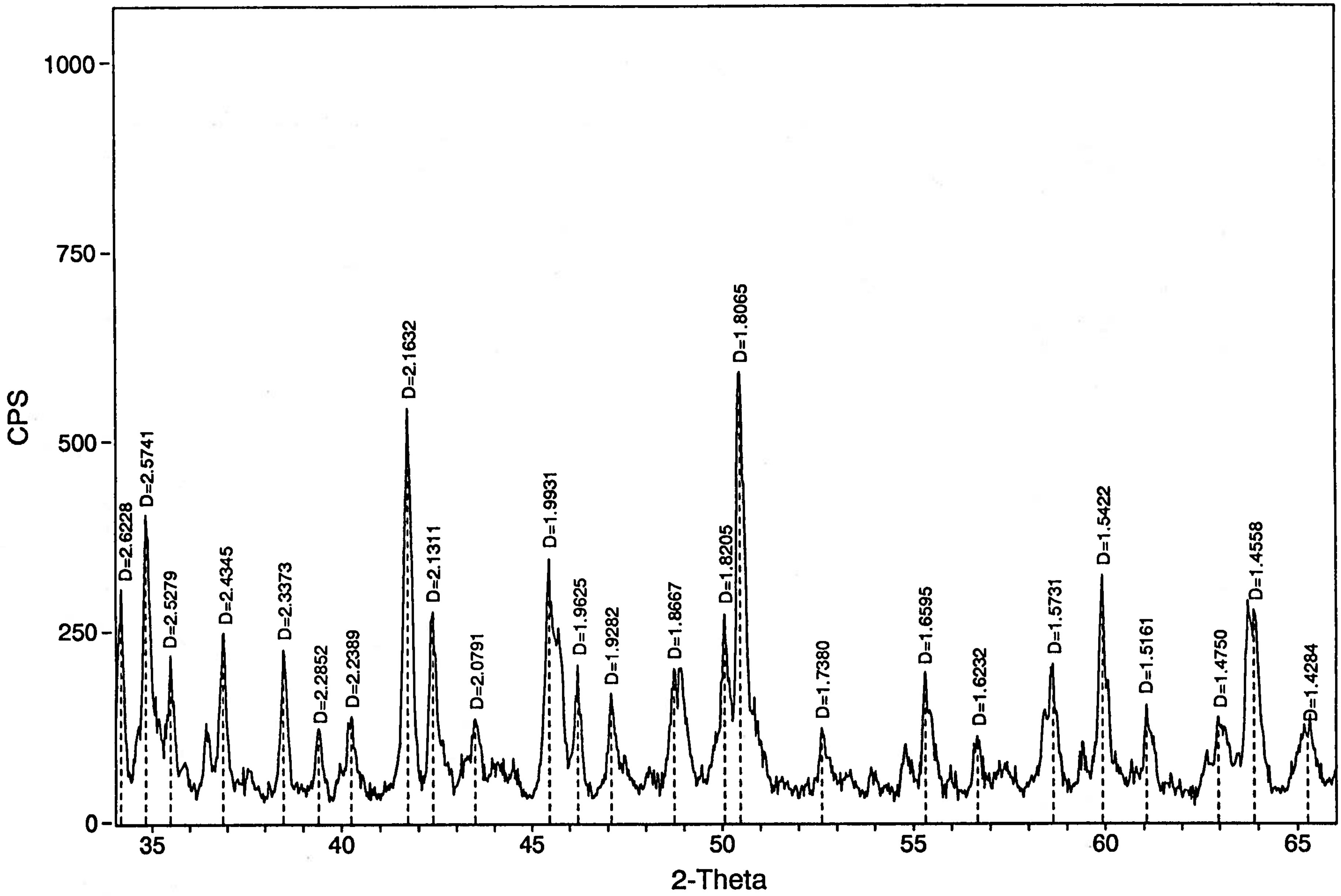


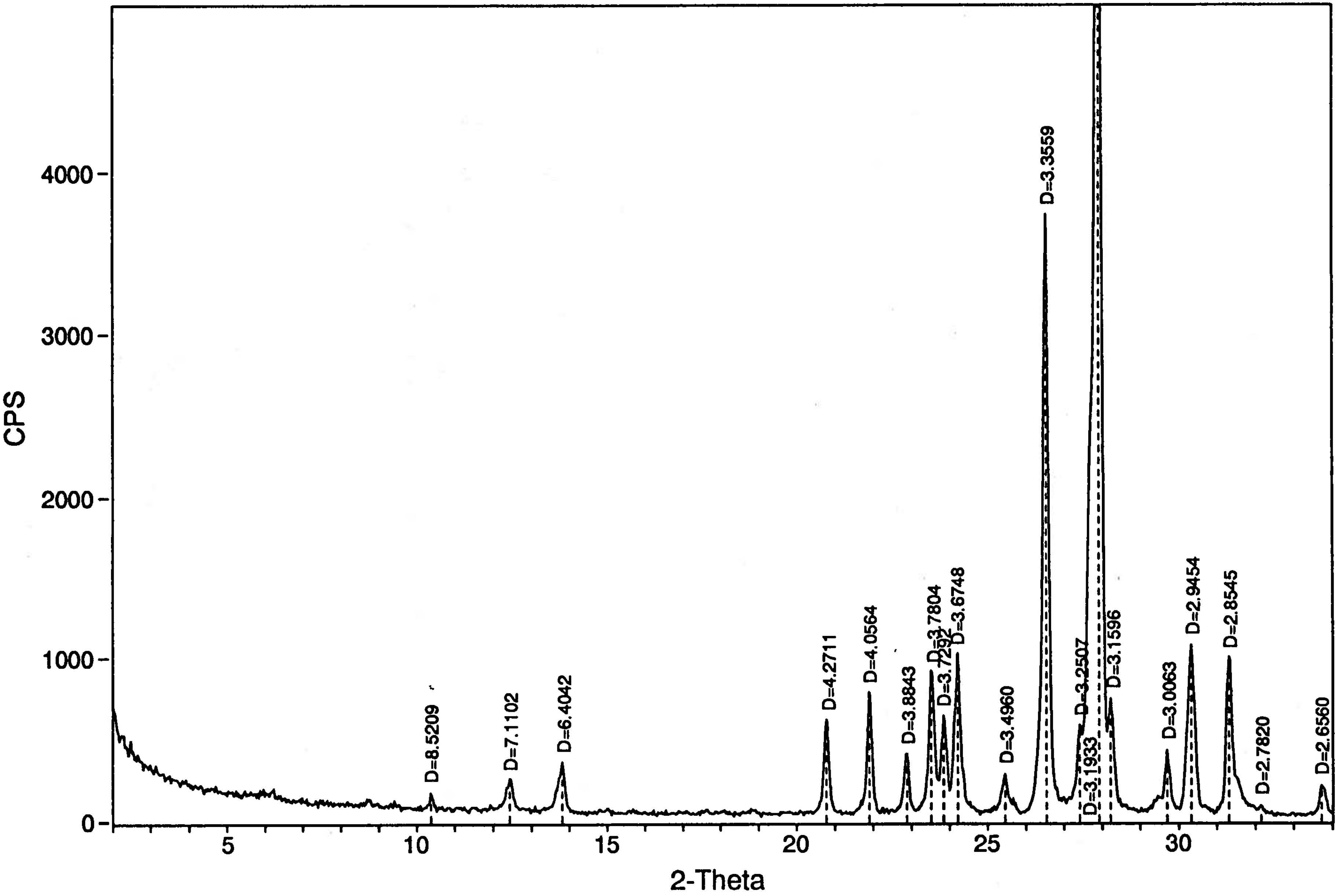
ID: C:\CO2\POST410.MDI: Postrun Autoclave 410 backpack

File: POST410.MDI Scan: 2-65.99/.03/1/#2134, Anode:CU Zero=0.0



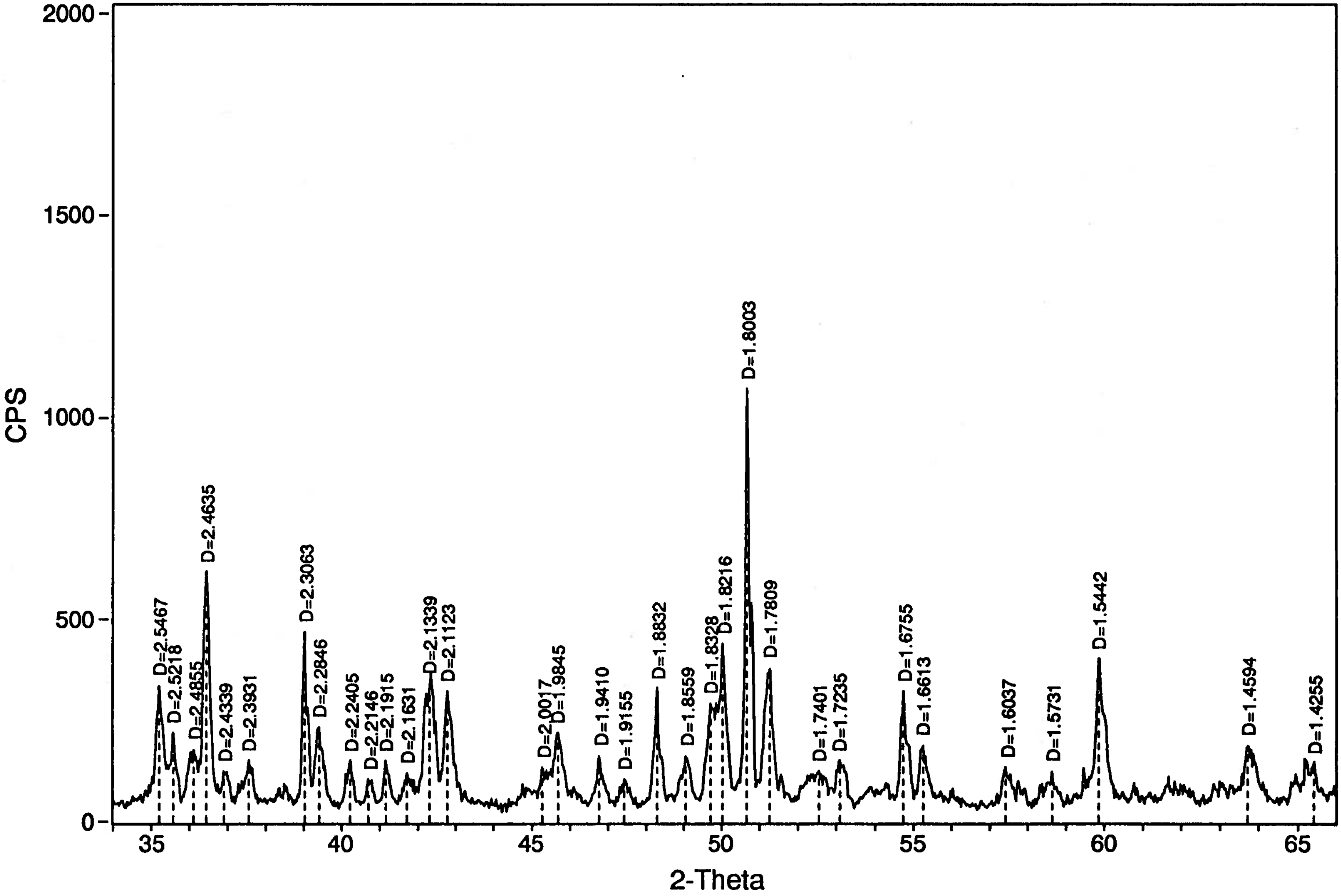
ID: C:\CO2\POST411.MDI: Postrun Autoclave 411 Backpack

File: POST411.MDI Scan: 2-65.99/.03/1/#2134, Anode:CU Zero=0.0



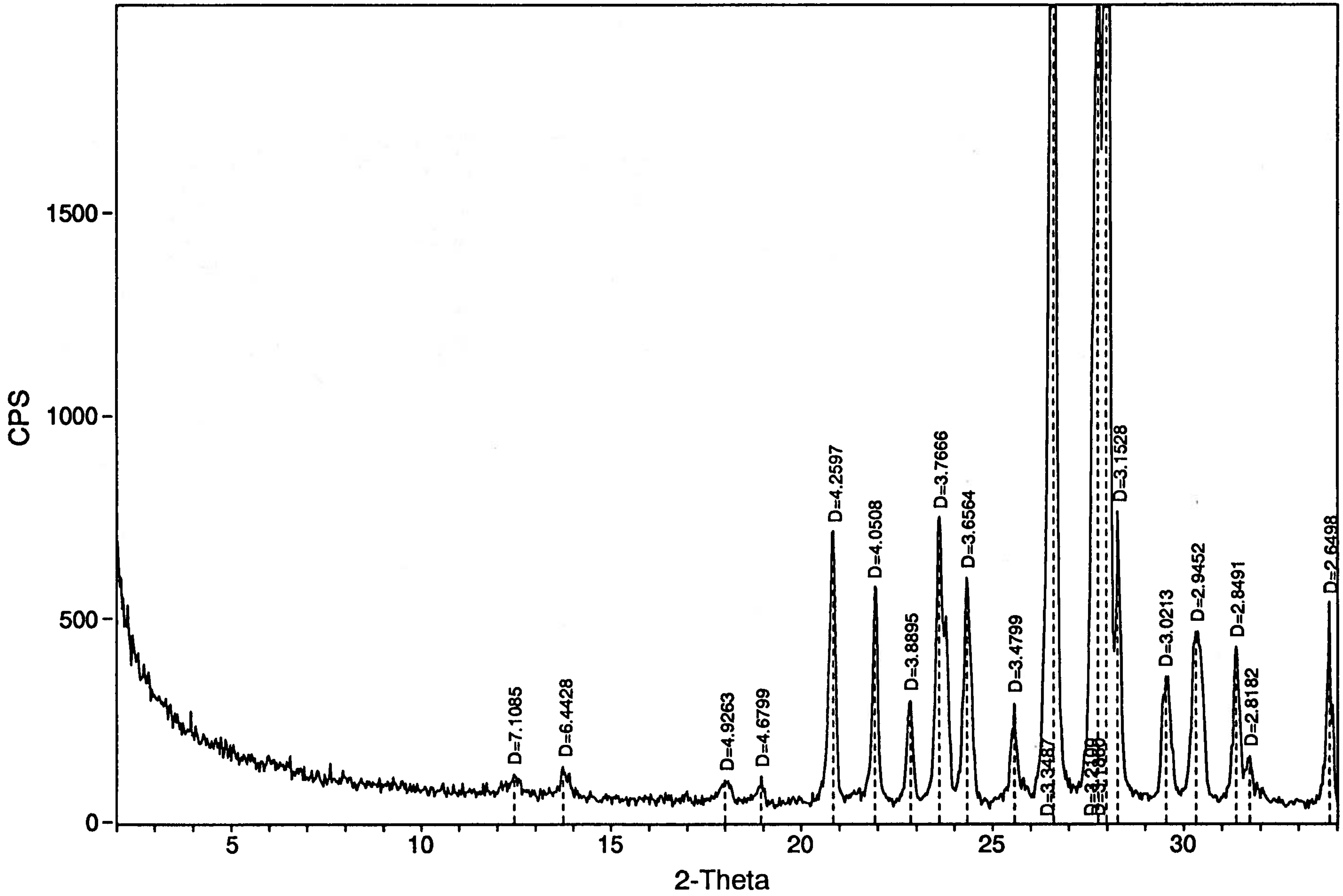
ID: C:\CO2\POST411.MDI: Postrun Autoclave 411 Backpack

File: POST411.MDI Scan: 2-65.99/.03/1/#2134, Anode:CU Zero=0.0



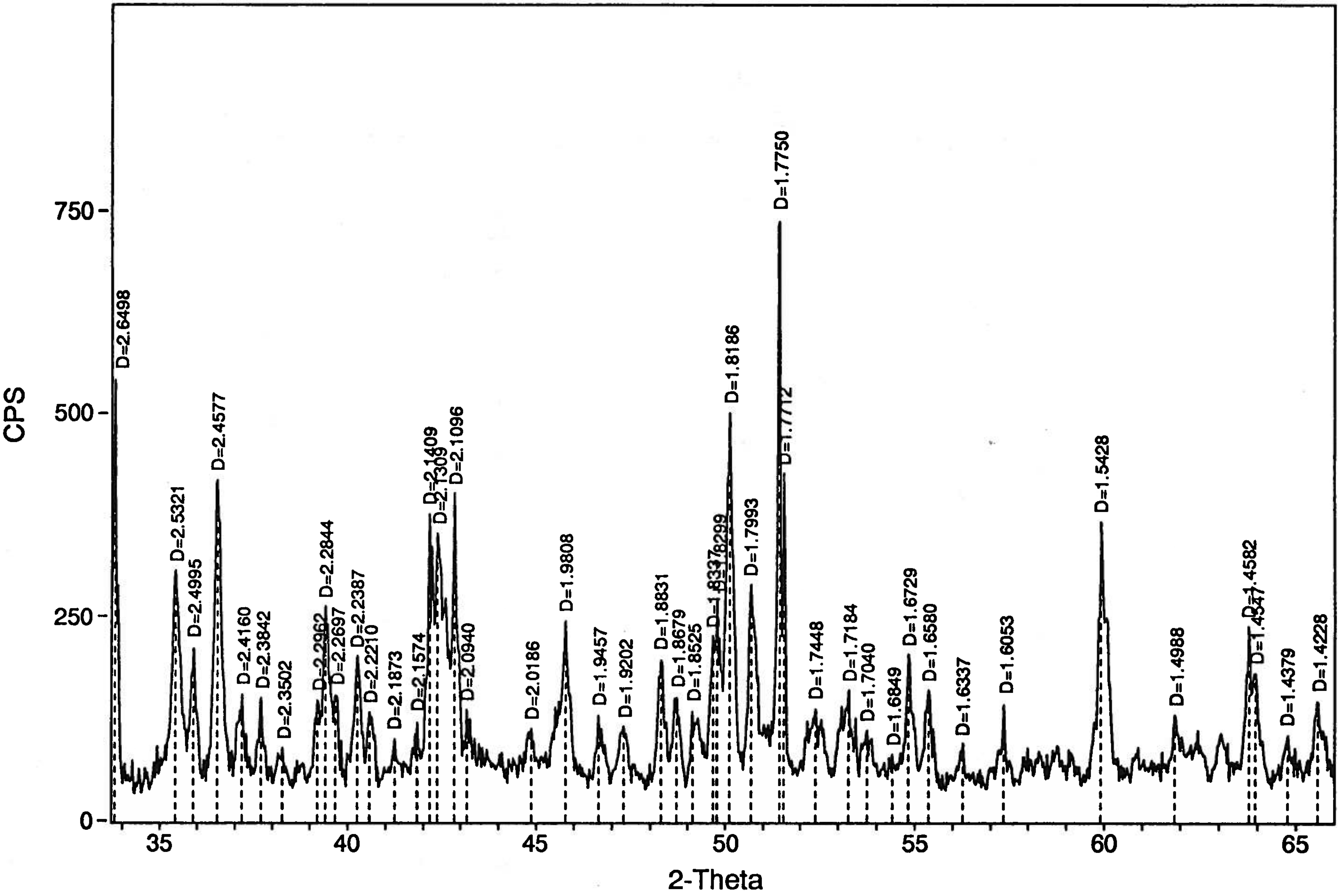
ID: C:\CO2\POST412.MDI: Postrun Autoclave 412 backpack

File: POST412.MDI Scan: 2-65.99/.03/1/#2134, Anode:CU Zero=0.0



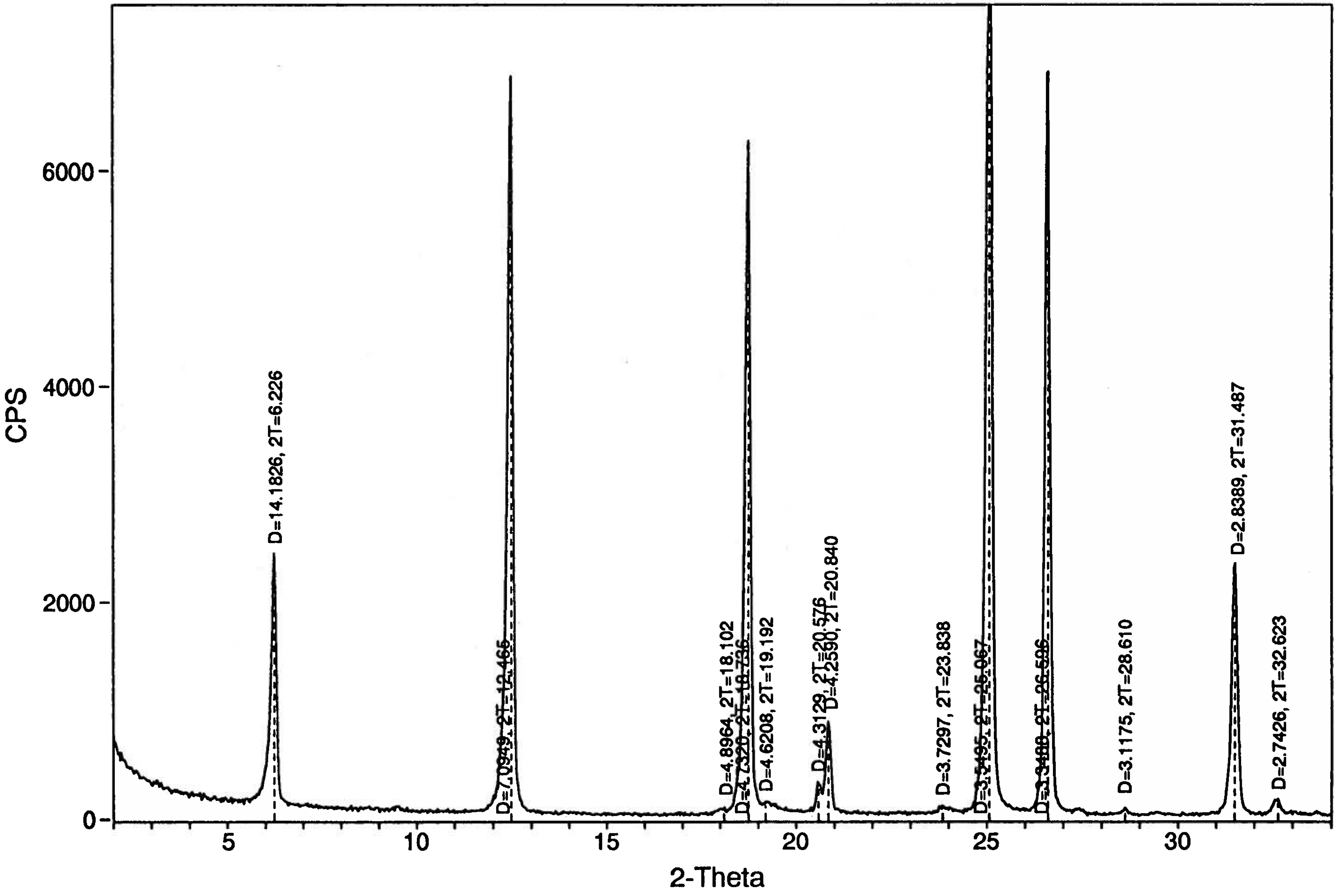
ID: C:\CO2\POST412.MDI: Postrun Autoclave 412 backpack

File: POST412.MDI Scan: 2-65.99/.03/1/#2134, Anode:CU Zero=0.0



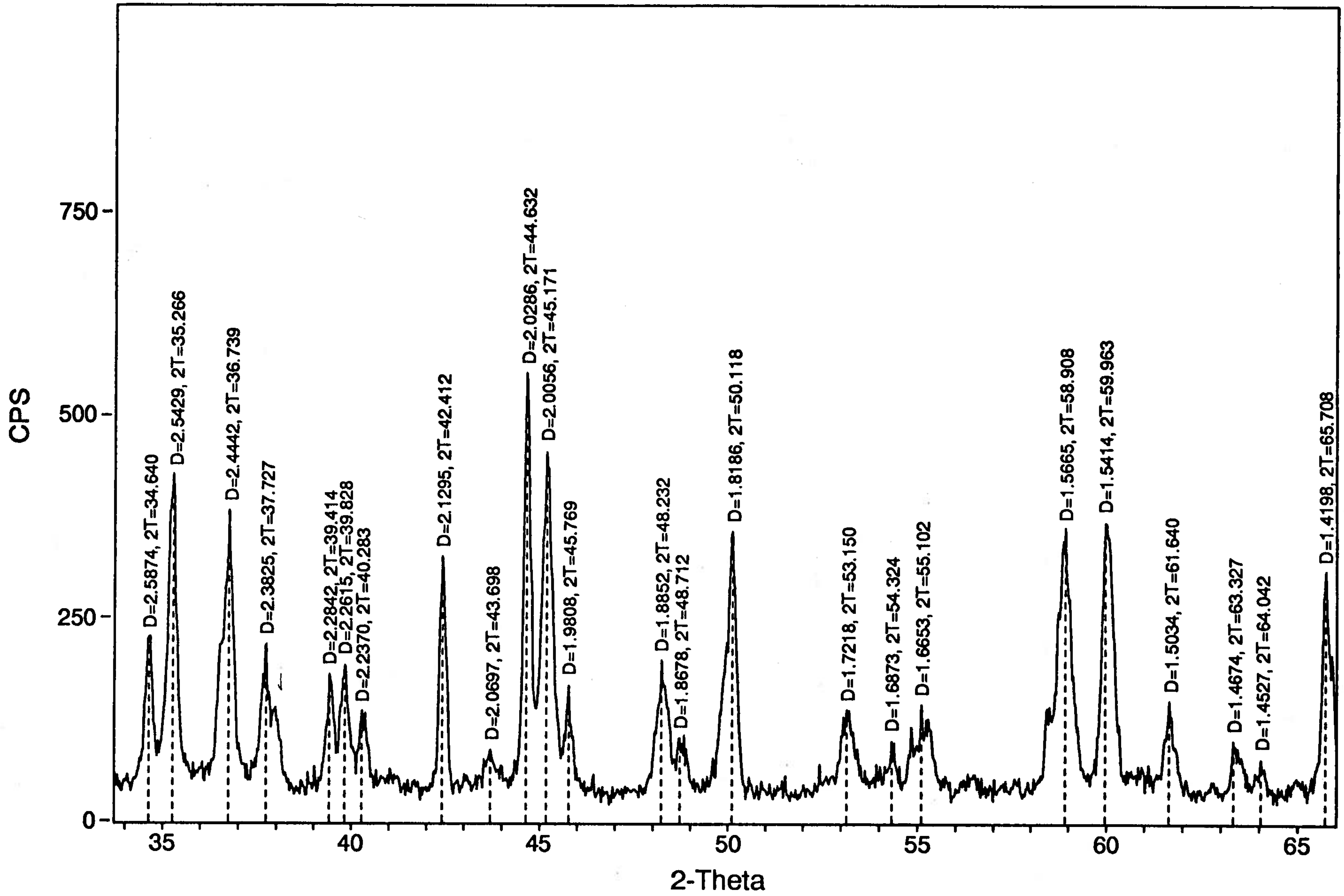
ID: C:\CO2\POST414.MDI: Postrun Autoclave 414 backpack

File: POST414.MDI Scan: 2-65.99/.03/1/#2134, Anode:CU Zero=0.0



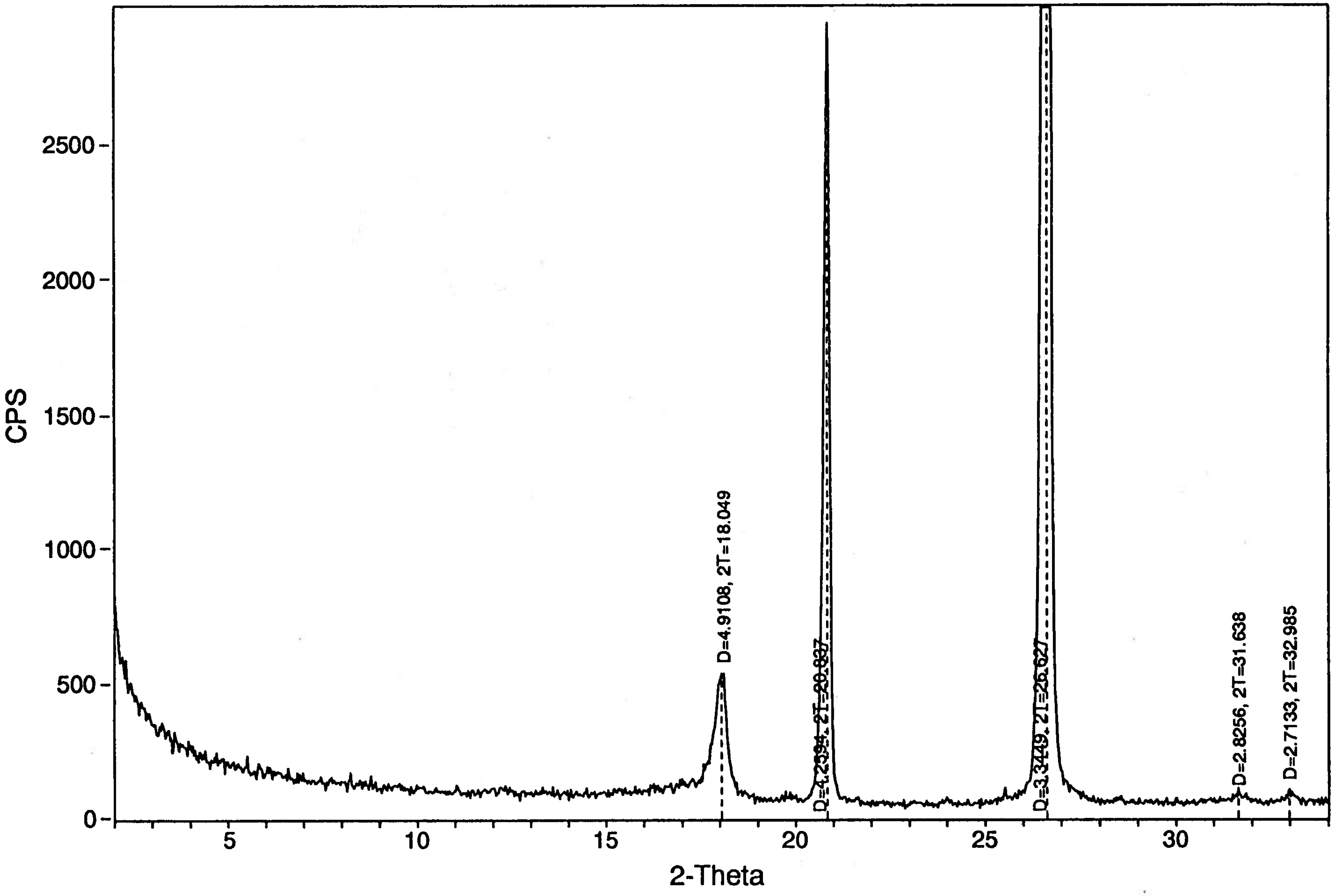
ID: C:\CO2\POST414.MDI: Postrun Autoclave 414 backpack

File: POST414.MDI Scan: 2-65.99/.03/1/#2134, Anode:CU Zero=0.0



ID: C:\CO2\POST437.MDI: Postrun Autoclave 437

File: POST437.MDI Scan: 2-65.99/.03/1/#2134, Anode:CU Zero=0.0



ID: C:\CO2\POST437.MDI: Postrun Autoclave 437

File: POST437.MDI Scan: 2-65.99/.03/1/#2134, Anode:CU Zero=0.0