Geological Circular 80-3

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HYDROLOGY AND WATER QUALITY OF THE EOCENE WILCOX GROUP: SIGNIFICANCE FOR LIGNITE DEVELOPMENT IN EAST TEXAS[1]

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ABSTRACT

Lignite development will place major demands on ground-water supplies. The Simsboro Formation and the Calvert Bluff Formation (a major lignite-bearing unit) of the Wilcox Group between the Colorado and Trinity Rivers constituted a test case to evaluate the availability and quality of ground water. Aquifer geometry (sand) was determined by comparing environmental geologic maps with subsurface sand-percent and net-sand maps constructed from electric logs (Kaiser, 1978). The combined maps correlate well and show that the Calvert Bluff Formation consists of a complex interfingering of coarse channel sands and fine interchannel muds. Sand outcrop areas occupying approximately 10 square miles separate much larger interchannel areas with few and minor sands. The Simsboro Formation consists of two parts — a thick multilateral sand (300 to 700 ft) in most of the southern outcrop belt and a series of channel sands (100 to 200 ft) interspersed with muds in the northern belt. Sands of the northern Simsboro belt are more like the Calvert Bluff channel sands than like the thick Simsboro sands.

Available hydrologic data suggest that Simsboro and Calvert Bluff sands have high hydraulic conductivity (6 to 20 m/day); interchannel muds have low hydraulic conductivity (1 to 2 m/day). Water compositions in the Simsboro and Calvert Bluff sands are similar and evolve similarly. Shallow ground water has a Ca-Mg-Cl-HCO_3 composition low in total dissolved solids (less than 500 mg/l). The water evolves over a depth range from 300 to 1,200 ft to become a Na-HCO_3 water. Change in composition probably results from ion exchange with clays (Ca^{++} for $2Na^{+}$) and solution of calcite (which contributes more Ca^{++} for exchange and increases HCO_3^- concentration). Poor quality water is largely restricted to shallow wells (less than 100 ft) in muddy parts of the Calvert Bluff Formation.

INTRODUCTION

The quantity and quality of ground water available from the Wilcox Group of east Texas will play a major role in lignite development. Lignite production in Texas from the Wilcox Group has grown from 2 million short tons in 1970 to 17 million tons in 1977, with a projected demand of 58 million tons in 1985 (Kaiser and Cooper, 1978). Now almost all lignite is used as fuel for mine-mouth power plants. This use will continue in the future. Power plants require approximately 10 acre-feet of water per year per megawatt of generating capacity, mostly for cooling (Texas Water Development Board, 1977). Currently, surface water is used exclusively, but in the future, ground water will also be in heavy demand for use either as cooling water or as replacement of surface water diverted to use by power plants. In addition, lignite mining may disturb recharge or flow characteristics and alter ground-water quality.

To evaluate the availability of ground water for lignite development or for other uses and to predict and possibly avoid deleterious impacts of mining, it is necessary to understand the hydrology and chemistry of ground water. To accomplish this, we have combined surface and subsurface studies of a part of the Wilcox Group, the major lignite-bearing unit and a major aquifer, to determine the geometry of different substrates that influence hydrologic characteristics and water quality.

[1]Publication authorized by the Director, Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas 78712

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HYDROLOGY

The Wilcox Group is composed of sands and muds that were deposited by ancient river systems (Fisher and McGowen, 1967; Kaiser *et al.*, 1978). The Wilcox Group between the Colorado and Trinity Rivers has been subdivided into three formations (Barnes, 1970; 1974). From oldest to youngest, they are: the Hooper Formation, composed of mud and sand; the Simsboro Formation, composed of sand; and the Calvert Bluff Formation, composed of sand and mud. This report will focus on the sand geometry in the Simsboro Formation, a major aquifer, and in the Calvert Bluff Formation, which is the main lignite-bearing formation and another major source of ground water in the region (figs. 1 and 2).

Sand geometry was constructed to delineate those parts of the Simsboro and Calvert Bluff Formations having different permeabilities. Subsurface net-sand and percent-sand maps constructed from electric logs (Kaiser, 1978; Kaiser *et al.*, 1978) were combined with surface mapping (Henry and Basciano, in press). The surface mapping is derived from a study of the environmental geology of the east Texas lignite belt. Environmental geologic map units are distinguished on the basis of substrate, soil, geomorphology, geologic process, vegetation, and land use.

Environmental geologic units have been grouped into two categories for the purpose of this study: 1) sands, whose substrate is composed of fine to coarse sands; and 2) muds composed of silty mud or thinly laminated sand and mud. Major sands were deposited within channels; the muds along with minor distributary sands were deposited in interchannel areas. Lignite deposits occur mostly within the interchannel areas.

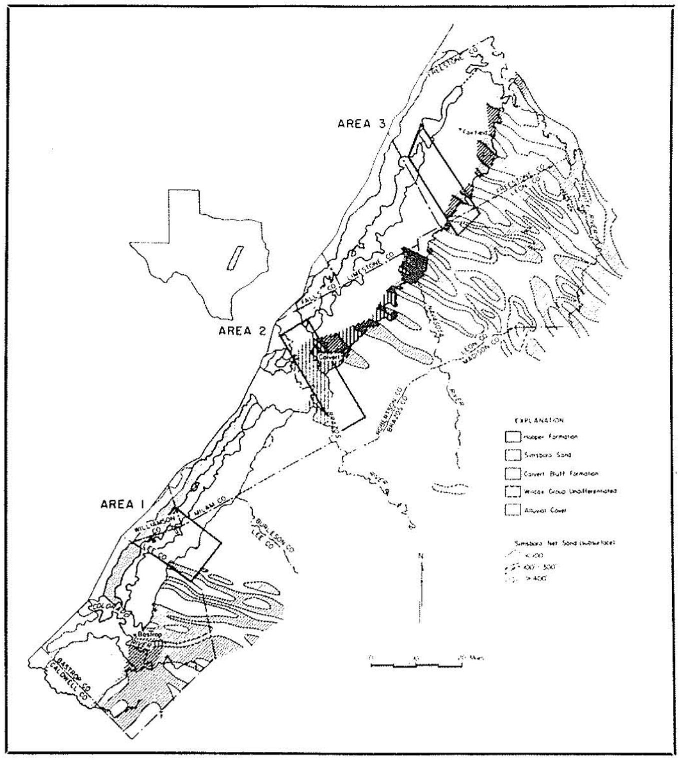

Figure 1. Simsboro Formation: surface and subsurface. Surface geology from Henry and Basciano (in press). Subsurface net sand from Kaiser (1978).

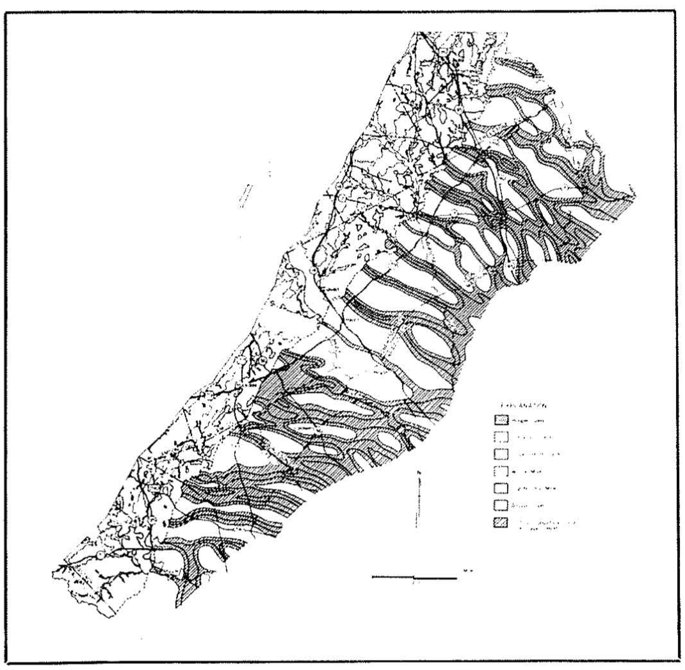

Figure 2. Calvert Bluff Formation: surface and subsurface. Surface geology from Henry and Basciano (in press). Subsurface percent sand from Kaiser *et al.* (1978).

Simsboro Formation

The map of the Simsboro Formation (fig. 1) was constructed from the surface mapping and from a net-sand map (Kaiser, 1978). The width of the outcrop area was assumed to be proportional to the thickness of the Simsboro Formation. Because the dip of the formation varies regionally from approximately 2° in Bastrop County to less than 0.5° in Freestone County, the width of outcrop for an equal thickness varies. The width increases to the northeast as the dip decreases even though the actual thickness of the Simsboro Formation decreases. Therefore regional comparison of outcrop width is not appropriate. Locally the dip is constant, thus the local comparisons made in this report are valid.

The Simsboro Formation, formerly thought of as a continuous sheet sand from the Colorado to the Trinity River, is composed of two distinct parts: 1) a multistory, multilateral sand deposit located between Lee and Falls Counties; and 2) multistory channel sand deposits located southwest of Lee County and northeast of Falls County (fig. 1). Both the surface and subsurface maps denote this.

Maximum sand development of the Simsboro Formation occurs between the Williamson/Milam county line and the town of Rockdale in Milam County. The environmental geologic map shows a continuous belt of sand which is the surface expression of the thick subsurface sands. Subsurface mapping by Kaiser (1978) shows that the multistory, multilateral sands are more than 700 ft thick in this area.

To the northeast the thick multilateral Simsboro deposits begin to thin in the subsurface as they grade into more dispersed channel sand deposits. Updip from the dispersed channel sand deposits, the Simsboro outcrop belt becomes wider. In the area of the Little and Brazos Rivers, the Simsboro Formation is largely covered by alluvium. However, the subsurface mapping shows that the Simsboro Formation continues beneath the alluvium, and the surface mapping shows a small isolated outcrop of Simsboro deposits where they had not previously been mapped.

Northeast of Falls County the Simsboro Formation thins: the net-sand map shows sands from 400 ft to less than 100 ft thick. The outcrop widens in the channel areas where the net sands are thick (300 ft) and pinches out in the interchannel areas where the net sands are thin (less than 100 ft). Subsurface mapping correlates well with environmental geologic mapping. For example, in western Freestone County (fig. 1) at the abandoned town of Simsboro, the wide outcrop pattern of channel sands is interrupted by interchannel deposits. Ironically, there is no Simsboro Formation at Simsboro.

The Simsboro channel deposits pinch out south of the Trinity River and do not continue to the river as was previously mapped by Barnes (1970). Subsurface mapping indicates a large interchannel area northeast of the pinch-out. The surface and subsurface mapping correlate well here also.

The multilateral sands of Milam County also break up to the southwest. In northern Bastrop County, the Simsboro deposits change to dispersed channel sand deposits as shown by both the surface and the subsurface mapping. South of the Colorado River the Simsboro Formation changes facies to strike-oriented, nearshore marine-dominated deposition. (Kaiser, 1978). It is no longer a major sand system either in the subsurface or at the surface.

Some questions of precise correlation still remain. For example, just north of Calvert an interchannel area mapped at the surface could correlate with either of two interchannel areas delineated in the subsurface (fig. 1). Without additional well control between the surface and the available well control, an exact correlation cannot be made.

Calvert Bluff Formation

The same approach used for the Simsboro Formation is used to delineate the sand geometry of the Calvert Bluff Formation. However, sand-percent maps were used rather than net-sand maps (Kaiser *et al.*, 1978).

The surficial outcrops of both channel sands and interchannel areas of the Calvert Bluff Formation had not been mapped prior to this study. Correlation of surface and subsurface mapping shows that high-percentage sand areas in the subsurface of the Calvert Bluff Formation are fluvial channel complexes that project updip to sand outcrops. Low-percentage sand areas are interchannel areas that project updip to mud outcrops (fig. 2). This correlation is especially good in the vicinity of Fairfield in Freestone County (fig. 3). Here the outcrop areas of the major subsurface channel complexes (greater than 100 ft thick) are relatively large (4 to 16 mi^2). Lignite deposits at an active lignite mine near Fairfield occur adjacent to these sands in the outcrop area of the interchannel muds (fig. 3). A channel divides two major lignite deposits, A and B, from a third deposit, C. A major channel complex west of Fairfield marks the southwest limit of commercial lignite.

A cross section of the Fairfield deposit (fig. 4) shows that lignites are associated with interchannel muds that include thin, fine-grained tributary sands. Lignite beds are separated laterally by the thicker, medium-grained sand channel complexes.

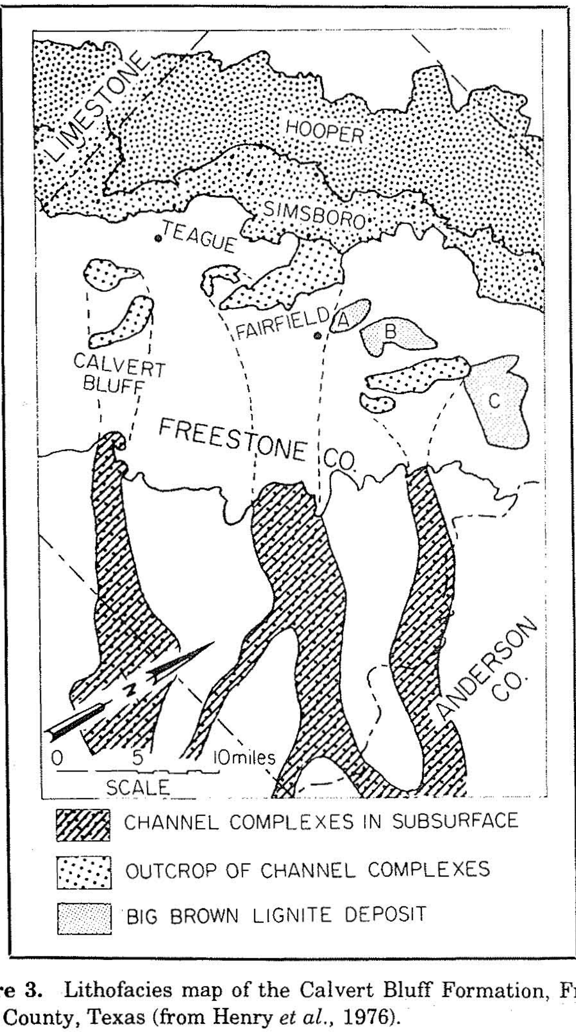

Figure 3. Lithofacies map of the Calvert Bluff Formation, Freestone County, Texas (from Henry *et al.*, 1976).

The environmental geologic maps indicate only the outcrop position of major sands. Sands less than about 20 ft thick do not have sufficient surface expression to be mapped. The fact that the outcrops of channel sands in the Fairfield area (figs. 2 and 3) are large and continuous suggests that the sands are few and thick rather than numerous and thin.

In the vicinity of Rockdale (fig. 2) the correlation of individual subsurface and surface units is not as good as it is near Fairfield. High sand percentages in the subsurface near Rockdale may be caused partly by several thin sands, too thin to be mapped by the surface study, alternating with mud in the Calvert Bluff Formation.

Comparison of Simsboro and Calvert Bluff Formations

Results of the environmental geologic mapping and subsurface analysis provide a detailed picture of the sand geometry of the Wilcox Group. The Simsboro Formation between the Colorado and Trinity Rivers is not a continuous sand body as previously considered but a complex of thick multilateral sands in most of the southern outcrop belt and multistory channel sand deposits interspersed with interchannel muds in the northern belt. The Calvert Bluff Formation consists of a complex interfingering of medium-grained channel sands and interchannel muds. Sand areas occupying approximately 10 square miles separate much larger interchannel areas with few and minor sands. Sands of the northern Simsboro belt are more like the Calvert Bluff channel sands than like the thick multilateral Simsboro sands.

Application to Hydrology

Surface/subsurface correlations illustrate the complexity of the sand geometry of the Wilcox Group. Previously the Simsboro and Calvert Bluff Formations were treated as a homogeneous aquifer because the information on geometry necessary to treat them more precisely was not available. Hydrology of the two units is largely a function of the distribution of sands and muds. Sands are more permeable than muds; the degree of permeability depends on the grain size and sorting of the sands. The Simsboro sands are coarse grained and highly permeable; available hydraulic conductivity values range from 6 to 20 m/day (W.F. Guyton, personal communication).

Hydraulic conductivities of channel sands in the Calvert Bluff Formation shown on the environmental geologic maps have not been determined directly. Hydraulic conductivity of the channel sands in this unit is probably similar to that of the Simsboro sands for two reasons: 1) the channel sands in the Calvert Bluff Formation are similar in grain size and sorting (Fisher, 1965) and in thickness to the coarse, permeable sands of the Simsboro Formation; 2) hydraulic conductivity values determined in undifferentiated Wilcox Group north of the Trinity River fall into two categories: one at 1 to 2 m/day that is associated with interchannel areas; and another at 6 to 20 m/day associated with sands. The higher values are similar to those of the Simsboro sands and are apparently from channel sands in the Wilcox strata. These sands are both recharge areas in outcrop and permeable conduits carrying ground water in the subsurface. The relatively high hydraulic conductivity of the interchannel areas

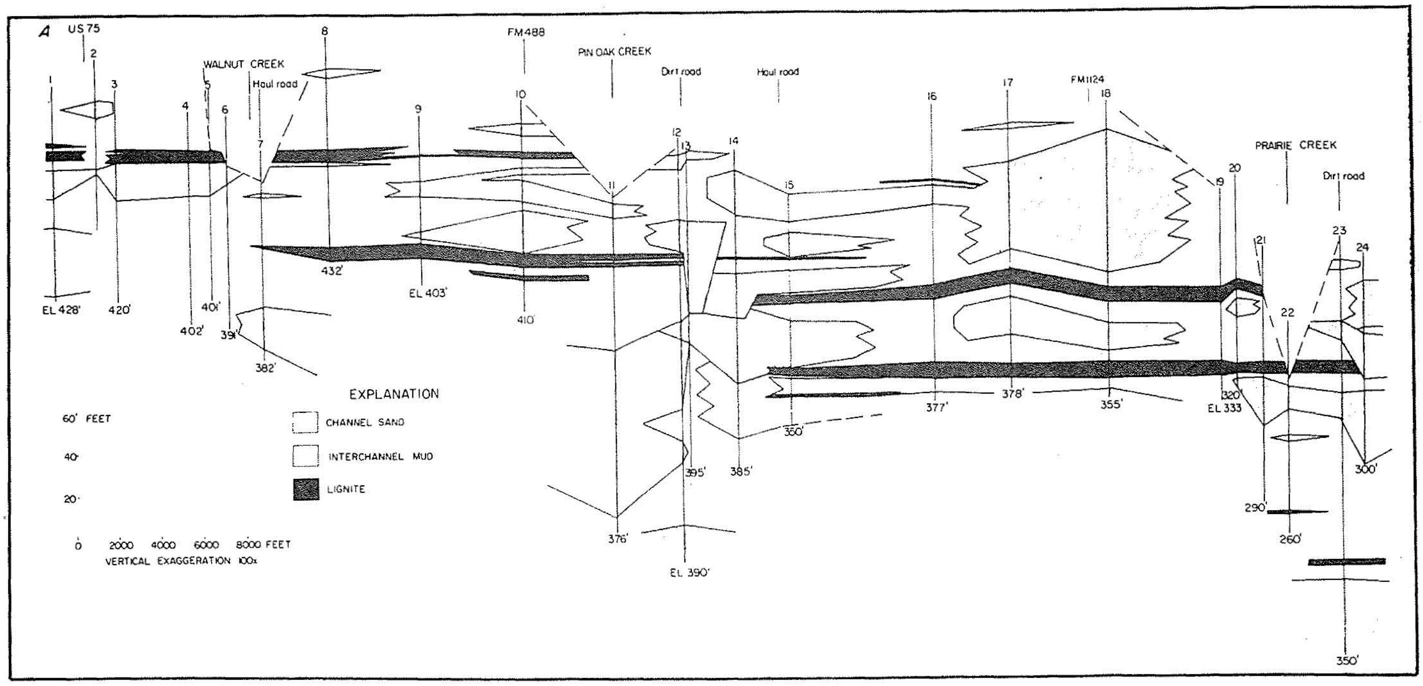

Figure 4. Strike section across lignite deposits, Freestone County, Texas (from Henry *et al.*, 1976). Most sands are thin, fine-grained tributary sands. Thicker sand complex in center of section is medium-grained, channel fill.

probably results from thin interbedded, very fine grained to fine-grained sands.

WATER QUALITY

Water quality was evaluated using available analyses of ground water from county reports and files of the Texas Department of Water Resources. Wells within the Wilcox Group are generally not subdivided according to producing interval. To distinguish Simsboro or Calvert Bluff wells, total well depths were compared with structure contours of the formation (W.R. Kaiser, unpublished data). It was generally assumed that a Wilcox well that penetrated Simsboro strata produced from the Simsboro Formation, whereas a well that penetrated only Calvert Bluff strata produced from the Calvert Bluff Formation. Some Simsboro wells downdip from the Simsboro outcrop may also produce from the overlying Calvert Bluff Formation, but most wells cutting the Simsboro Formation are believed to be screened primarily in the Simsboro Formation. Usable analyses were obtained from 181 Calvert Bluff wells and 153 Simsboro wells.

Three areas were selected within the regional study area to represent geographic and facies variations within the formations (fig. 1). Groups of wells were identified within each area so that water quality within the two formations could be compared locally and geographic and facies influences could be evaluated.

The analyses were plotted in two ways to illustrate water quality and to aid in understanding the character, controls, and evolution of water chemistry. Analyses were plotted on trilinear (Piper) diagrams to illustrate ion proportions (figs. 5 and 6). Individual ions were plotted against each other or against depth to illustrate relative proportions and evolutions (figs. 7 and 8). Eight different groups were so plotted, including the total set of Simsboro and Calvert Bluff analyses and the analyses from both formations in the local areas. In addition, ion activities and mineral equilibria were calculated by the computer model WATEQF (Plummer *et al.*, 1976). Representative analyses are given in table 1.

Chemical Evolution of Ground Water

The various plots show that water composition in the Calvert Bluff and Simsboro Formations is similar both regionally and locally. With only a few minor exceptions discussed below, the plots are identical for each formation. Because they are so similar, this discussion will focus on the overall chemistry; individual areas are discussed only where they illustrate important differences.

The plots show that both formations exhibit a wide range of compositions from Ca-Mg-Cl-HCO_3-(SO_4) waters to Na-HCO_3 waters. Depth vs. ion plots show that sodium and bicarbonate increase with depth whereas calcium, magnesium, sulfate, and chloride generally decrease with depth, both in relative and total concentrations. Thus, Ca-Mg-Cl-HCO_3-(SO_4) waters occur at shallow depths, whereas Na-HCO_3 waters occur at greater depths.

Total dissolved solids (TDS) are low and range from approximately 200 to 1,000 mg/l for most waters and increase irregularly with depth. A few waters restricted to shallow wells in the Calvert Bluff Formation have higher TDS, and higher chloride and sulfate concentrations. Their significance is discussed below.

The plots also show that there are direct or inverse relationships between many of the constituents. Sodium and bicarbonate increase together in a 1 to 1 ratio of molality or milliequivalents. Calcium and sodium, or calcium and bicarbonate show an inverse relationship. As either sodium or bicarbonate increases, calcium generally decreases, although there is considerable scatter at low concentrations. Thus, water in both formations evolves from a Ca-Mg-Cl-HCO_3-

Table 1. Representative water analyses.*

	Shallow Ca-Mg-Cl-HCO_3		Intermediate Composition and Depth		Deep Na-HCO_3		Shallow-high Dissvolved Solids
	Simsboro	Calvert Bluff	Simsboro	Calvert Bluff	Simsboro	Calvert Bluff	Calvert Bluff
Well No.**	39-51-903	39-53-702	39-59-802	59-04-502	59-12-205	59-03-815	39-59-803
Depth (ft)	22	52	420	575	1405	978	40
Ca	61	69	11	22	3	5	255
Mg	7	9	4	8	1	3	58
Na	24	56	88	94	434	222	200
HCO_3	203	220	211	264	890	489	159
SO_4	12	7	23	35	4	4	462
Cl	42	92	29	34	169	70	494
NO_3	1.5	14	0.4	2.0	0.4	0.4	3.0
SiO_2	34	43	16	17	14	16	55
TDS	282	398	275	333	1064	561	1606
T(°F)	76	76	78	75		79	78
pH	7.4	7.1	8.2	7.6	8.0	8.1	6.6

*Source: Texas Department of Water Resources. All concentrations in milligrams/liter.
**Texas State well-numbering system.

(SO_4) composition in near-surface recharge areas to a Na-HCO_3 composition as it progresses downdip. The transition from one composition to another is gradational and appears to occur at similar depths for both formations.

Similar evolution of ground water in clastic aquifers has been noticed previously; it was first described by Foster (1950) for Tertiary aquifers of the Atlantic and Gulf Coastal Plains. Pearson (1966) found a similar range of water chemistry for the Carrizo Sand of south Texas. Both attribute the evolution to a combination of: 1) solution of calcite; and 2) ion exchange with montmorillonite clays. The appropriate reactions are:

$$CaCO_3 + CO_2 + H_20 \longleftrightarrow Ca^{++} + 2\,HCO_3^- \quad (1)$$

$$Ca^{++} + \text{Na-clay} \longleftrightarrow 2\,Na^+ + \text{Ca-clay} \quad (2)$$

By this model, as water moves through the substrate, calcite dissolves releasing one calcium ion and two bicarbonate ions. With sufficient solution, the water becomes saturated with respect to calcite, and solution ceases. At the same time, however, calcium exchanges with clays, which release two sodium ions for each calcium ion taken up. As calcium is

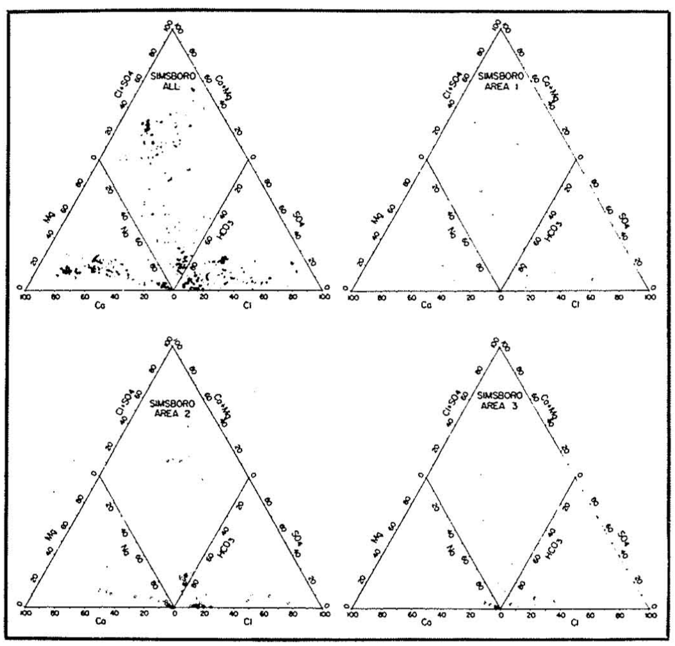

Figure 5. Trilinear diagrams of ground water from the Simsboro Formation. Diagrams are constructed using milliequivalents per liter. Locations of areas 1, 2, and 3 are shown on figure 1.

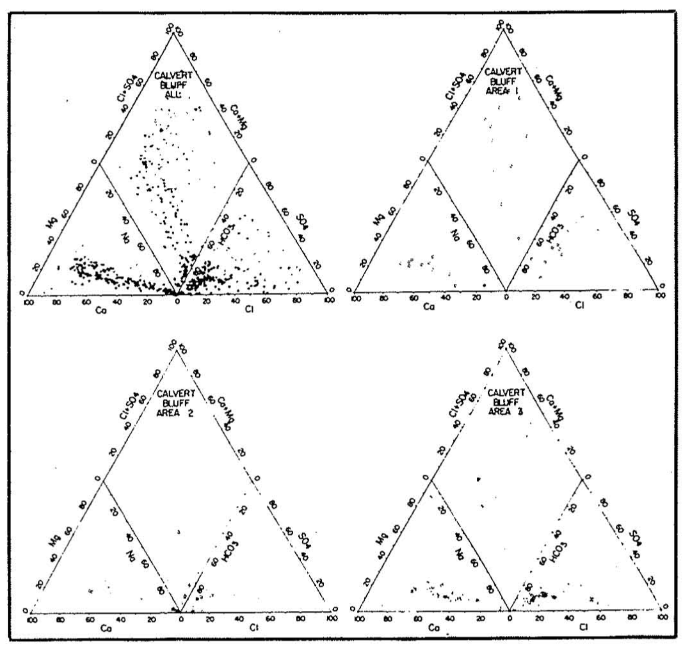

Figure 6. Trilinear diagrams of ground water from the Calvert Bluff Formation. Diagrams are constructed using milliequivalents per liter. Locations of areas 1, 2, and 3 are shown on figure 1.

depleted by exchange, the water becomes undersaturated with respect to calcite and more calcite can dissolve. Thus a continuous process occurs. Calcite dissolves, releasing calcium and bicarbonate. Calcium is taken up by clays, which release sodium. As calcium is depleted, more calcite dissolves.

If these reactions are actually occurring, several relationships between various ions ought to appear: 1) calcium and bicarbonate ought to increase together in a 1 to 2 molal ratio until calcite saturation occurs, and then calcium ought to drop with increasing bicarbonate; 2) shallow, less evolved water may be undersaturated with respect to calcite, but as the waters evolve they should become saturated and remain so; 3) sodium and bicarbonate ought to increase in a 1 to 1 molal ratio; 4) sodium and calcium ought to be inversely related at a 2 to 1 ratio.

Inspection of figures (7 and 8) shows that these relations do hold. Calcium and bicarbonate increase together at low concentrations in shallow waters. A peak calcium concentration of 2.5 millimoles (mmoles) is reached at a bicarbonate concentration of 5 mmoles. At higher bicarbonate concentrations, calcium drops to very low levels.

Calcite equilibrium was determined from comparison of ion activity products with solubility products calculated by WATEQF. Waters in equilibrium with calcite should have a saturation index equal to 0. The saturation index is equal to the log base 10 of the activity product of calcium and carbonate divided by the solubility product.

There is considerable scatter in saturation indices, but, in general, waters that are considerably undersaturated with respect to calcite (saturation index less than -1) are restricted to shallow wells (less than 100 ft deep). Saturation indices of waters from all deeper wells are between +1 and -1; most waters are near equilibrium. The scatter is probably due to the fact that pH and bicarbonate concentrations for these waters were not measured in the field.

Most sodium and bicarbonate concentrations fall along a 1 to 1 molal ratio. However, there is considerable scatter below a concentration of 4 mmoles of sodium or bicarbonate with many shallow waters having excess bicarbonate relative to sodium. For these low concentrations, most bicarbonate is coming from calcite solution (equation 1) as shown by the relationship between calcium and bicarbonate.

Considerable scatter also occurs in the sodium-calcium plots, particularly for waters from the Calvert Bluff Formation. However, an inverse relationship exists between the two ions, and most analyses show the expected 2 to 1 ratio.

Thus Simsboro and Calvert Bluff waters are very similar and are of high quality. In light of the similarities in substrate of the Simsboro and Calvert Bluff Formations discussed above, this is not surprising. For example, in area 3 (fig. 1) the Simsboro Formation consists of channel sands with a net thickness of as much as 300 ft. The Calvert Bluff Formation in the same area ranges from 40 to 65 percent sand. Net sand thickness reaches 600 ft (Kaiser, 1978). In area 2 the Simsboro Formation ranges from 300 to 500 ft thick; percent and net sand in the Calvert Bluff Formation are 50 to 65 percent and slightly less than 400 ft, respectively. Most water produced from the Calvert Bluff Formation, especially from "deeper" wells, is probably from sands that are similar in thickness and lithology to sands of the Simsboro Formation.

Origin of High Dissolved Solids Water

Poor quality water does occur in the Calvert Bluff Formation but is restricted almost entirely to shallow wells. Because poor quality is largely a reflection of higher chloride and/or sulfate concentration, understanding controls of these two constituents helps to explain the origin of poor quality water.

Both chloride and sulfate concentrations show an apparent decrease with depth. Most waters with chloride concentrations greater than 2 mmoles/liter (approximately 70 mg/l) are from shallow wells in the Calvert Bluff Formation; only a few are in the Simsboro Formation. These higher chloride concentrations probably result from two processes: 1) leaching of soluble chloride compounds from muddy parts of the Calvert Bluff Formation; and 2) human contamination.

Comparison of sodium vs. chloride plots in Calvert Bluff waters illustrates these processes (fig. 8). Two trends are apparent: 1) an increase in sodium without an increase in chloride, which results from ion exchange discussed above; and 2) an increase in both sodium and chloride in roughly 1 to 1 molal proportion. Comparison of the sodium-chloride and depth-chloride plots shows that all waters that exhibit a near 1 to 1 ratio of sodium and chloride are from Calvert Bluff wells less than about 300 ft and mostly less than 100 ft deep. Many other shallow wells and all deeper wells in the Calvert Bluff Formation have low chloride concentrations. Similarly almost all Simsboro wells have low chloride concentrations, and the correlation between sodium and chloride is weak.

Leaching of soluble chloride compounds in muds is probably the dominant source and is illustrated by the composition of water draining from lignite spoil piles. Because lignite and lignite mining are largely in mud-rich interchannel areas, spoil is composed predominantly of mud. Water draining from spoil at one mining area commonly contains several hundred and up to 1,690 mg/l chloride (French, 1979). Leaching of chloride probably occurs much more rapidly from the disturbed spoil than from undisturbed substrate; nevertheless, the source and process are similar.

Human contamination, for example from septic tank wastes, should be restricted to areas of habitation. The location of wells in relation to possible sources of contamination is not known. However, at least some of the shallow wells are probably dug wells used for domestic supply and could be contaminated.

Higher chloride concentrations should be more common in the Calvert Bluff Formation that in the Simsboro Formation by either mechanism. The Calvert Bluff Formation contains considerably more mud than the Simsboro Formation. Also, population on the Calvert Bluff outcrop, although not especially high, is much greater than on the Simsboro outcrop. Areas of Calvert Bluff outcrop have been farmed extensively since the late 1800's; areas of Simsboro outcrop are largely uncleared, post-oak forest (Henry and Basciano, in press).

There are no known reactions that can remove chloride from waters with the moderate concentrations found here. Why then does chloride decrease with depth? If human contamination is a source, the volume of contaminated water should be minor and should not have had sufficient time to reach even moderate depths. Also, if chloride-rich waters occur only in muds, then only shallow wells that produce water exclusively from muds should have high chloride concentrations. Deeper wells would encounter clean sands, along with the muds. Waters produced from these sands have low chloride contents because they evolved from shallow

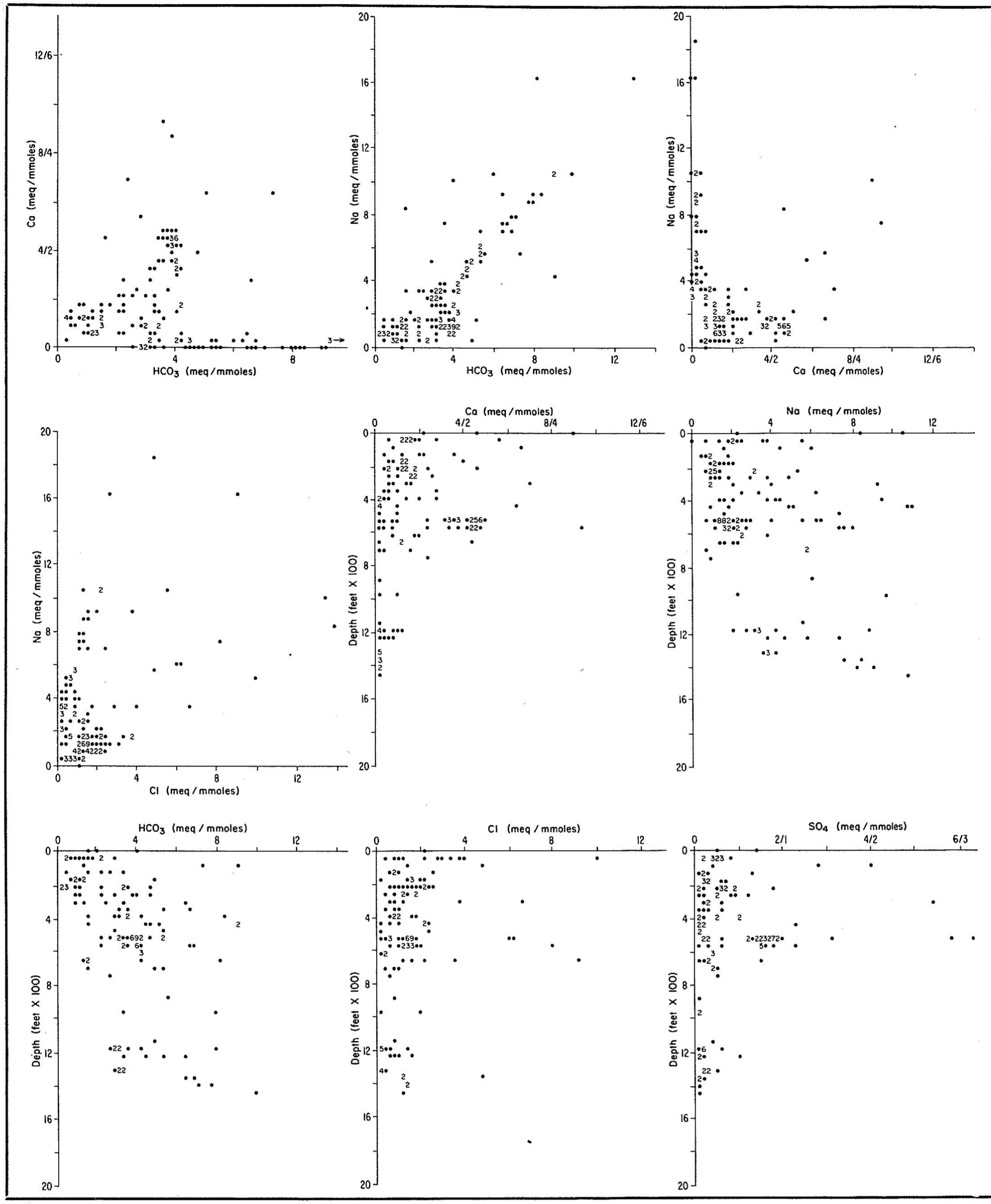

Figure 7. Crossplots of ground-water chemistry of Simsboro Formation. Ion concentrations are in millimoles and milliequivalents.

waters with low chloride concentrations. Muddy parts of the Wilcox Group at greater depth may also contain chloride-rich waters. However, water in a well through a substrate with 50 percent sand, typical of the Calvert Bluff Formation, will come

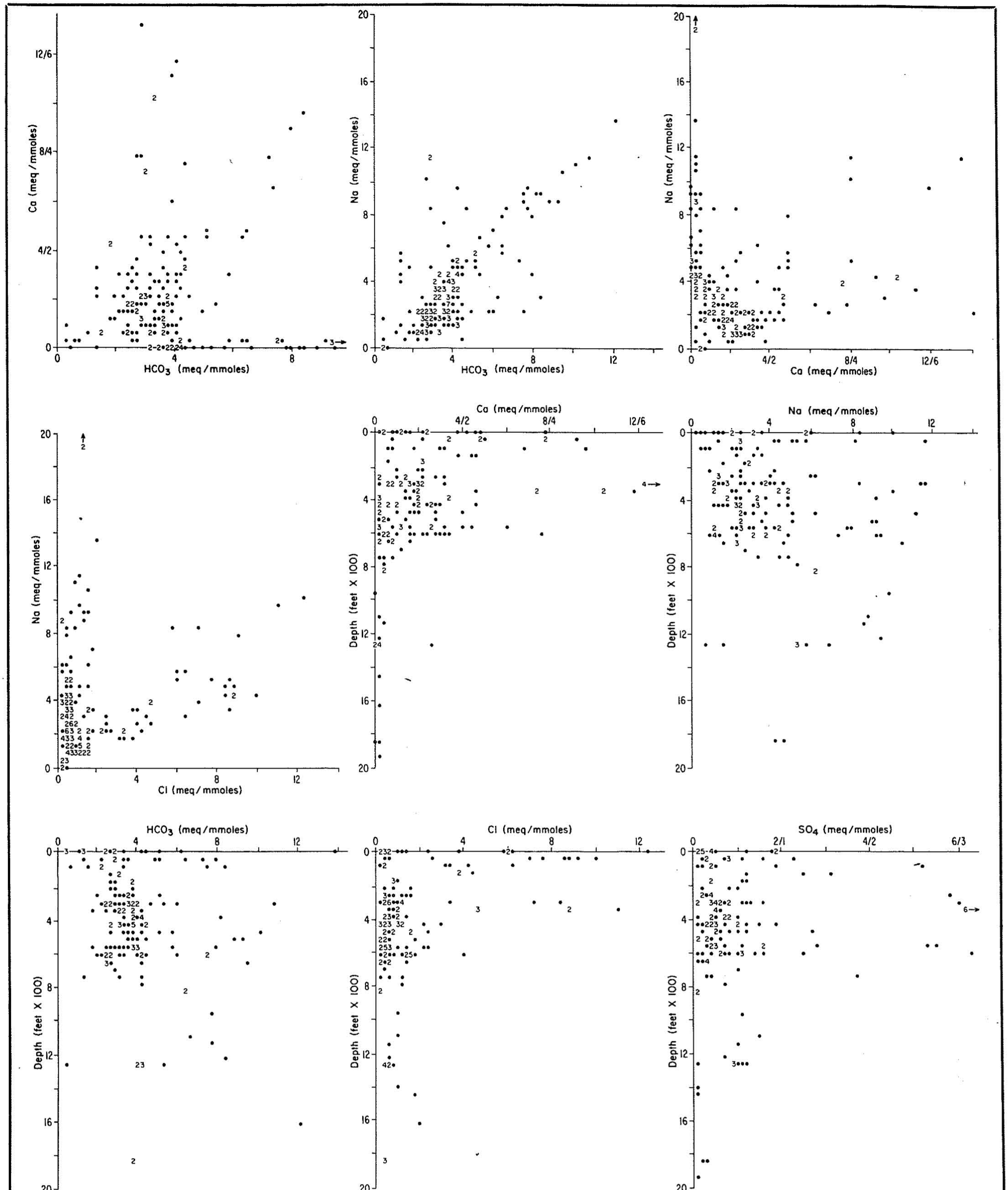

Figure 8. Crossplots of ground-water chemistry of Calvert Bluff Formation. Ion concentrations are in millimoles and milliequivalents.

largely from the sands because of their higher permeability. The wells are likely to be screened preferentially in the sands. Thus the chloride-rich waters are simply not abundant and are overshadowed by low-chloride waters.

Sulfate is a major constituent only of Calvert Bluff waters in area 1 (fig. 1). Calvert Bluff waters from areas 2 and 3 and all Simsboro waters have low sulfate concentrations relative to chloride or bicarbonate. Sulfate could be contributed by oxidation of pyrite in shallow, muddy parts of the Calvert Bluff Formation, but restriction of this mechanism to area 1 is unlikely. Another factor may be the transition in the Wilcox Group to strandplain/lagoonal facies south of the Colorado River (Fisher and McGowen, 1967). Near area 1 the Calvert Bluff Formation is fluvial but perhaps more marine-influenced, and hence richer in sulfate.

The decrease in sulfate with depth may be similar to the decrease in chloride with depth. High-sulfate waters are simply being overshadowed by low-sulfate waters from thick sands. However, reduction of sulfate to H_2S and eventual precipitation of FeS_2 is probably also a factor.

CONCLUSIONS

The comparison of surface and subsurface mapping with hydrologic and water quality data reveals the following:

1) Surface and subsurface correlate well. The Simsboro Formation is composed of multilateral sands in most of the southern part of the study area and channel sands in most of the northern part. The Calvert Bluff Formation throughout is composed of channel sands within large interchannel areas similar to the Simsboro Formation in the northern area.

2) High permeability is associated with the multilateral and channel sands of the Simsboro Formation and channel sands of the Calvert Bluff Formation.

3) Water quality is generally good and similar for both the Simsboro and the Calvert Bluff Formations.

4) Poor water quality is restricted to shallow wells in muddy parts of the Calvert Bluff Formation.

APPLICATION TO LIGNITE DEVELOPMENT

Knowledge of variations in ground-water hydrology and quality has several applications to strip mining. Knowledge of the geometry and permeability variations can be used to determine ground-water availability and also to locate wells for maximum yield and development of the aquifer.

Mining in the Calvert Bluff Formation will clearly not intersect Simsboro sands. Also, because lignite occurs in interchannel areas, mining largely will not intersect major channel sands in the Calvert Bluff Formation. Thus most potential problems of ground-water discharge into a mine or disruption or pollution of the aquifer should be avoided simply as a result of the natural distribution of lignite. Some exceptions are likely, for example, where lignite underlies a channel sand. Comparison of lignite distribution in a mining area with figure 2 should show where this could occur.

Ground water associated with lignite in interchannel muds probably is of poorer quality than most Calvert Bluff water. Sample 39-59-803 (table 1) may be representative of this kind of water. However, some water discharging from spoil at an active lignite mine has considerably higher TDS and sulfate concentrations than does sample 39-59-803. Thus some degradation of ground water should be expected. The significance of this problem can be evaluated by a combination of onsite study and the regional information presented here.

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