DEVELOPMENT OF DISSOLUTION BRECCIAS, NORTHERN DELAWARE BASIN, NEW MEXICO AND TEXAS

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Abstract

Beds of dissolution breccia are persistent in the Castile-Salado evaporites in the western part of the Delaware Basin. Dissolution breccia consists of subangular to somewhat rounded and elongate fragments of individual laminae of calcite-laminated anhydrite set in an anhydrite matrix. Collapse breccias consisting of angular fragments of laminated anhydrite with little or no matrix often overlie dissolution breccias or may occur separately within the anhydrite some distance above dissolution horizons. Correlation of individual calcite-laminated anhydrite laminae associated with dissolution breccias with the same laminae associated with halite beds shows that dissolution breccias are equivalent to halite beds. Even the thinnest halite beds in the eastern part of the basin once extended west of their present distribution, probably to near the western margin of the basin. The tracing of identified dissolution horizons to large areas of deep dissolution west of existing halite beds shows that it is removal of salt from the lower part of the Salado and upper part of the Castile Formations that has caused collapse of the depressions.

Introduction

A core of laminated anhydrite of the Castile and Salado Formations collected from Culberson County, Texas, in an area that had been subjected to complete dissolution of salt, contained a number of layers of anhydrite breccia (fig. 1, location D). Correlation of individual laminations in the anhydrite over distances up to 70 mi (113 km) (Anderson and Kirkland, 1966; Kirkland and Anderson, 1970) makes it possible to also correlate the breccia beds with particular salt horizons and to demonstate that the breccia was formed as a result of dissolution of salt. This approach has resulted in a more accurate appraisal of the original distribution of halite beds in the Delaware Basin (Anderson and others, 1972).

In these earlier works, the dissolution breccias were shown to relate to areas of dissolution, and the dissolution horizons were identified only in a general way. In this report we relate the dissolution breccias to specific salt beds in the upper part of the Castile and lower part of the Salado Formations, trace certain dissolution horizons to specific features of dissolution within the basin, and suggest some concepts concerning origin of the dissolution breccias and their relationship to collapse breccias.

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Breccia beds

Dissolution breccias

Dissolution breccias are characterized by an impure anhydrite matrix that suspends subangular to rectangular-elongate fragments of laminated anhydrite (fig. 2). In some samples fragments are quite small (less than 0.5 cm), rounded, and suspended in random orientations within a matrix that comprises more than half the volume of material. In other samples the fragments are large (greater than 2 cm), with a more or less parallel orientation to the stratification of the overlying and underlying units and associated with a relatively small amount of matrix.

The thicknesses of the beds of dissolution breccia range from a few centimeters to several meters and are approximately proportional to the thicknesses of correlative salt beds. The textures and proportions of matrix to fragments appear to be related to the thicknesses of the salt laminae separating the individual or sets of anhydrite laminae in the

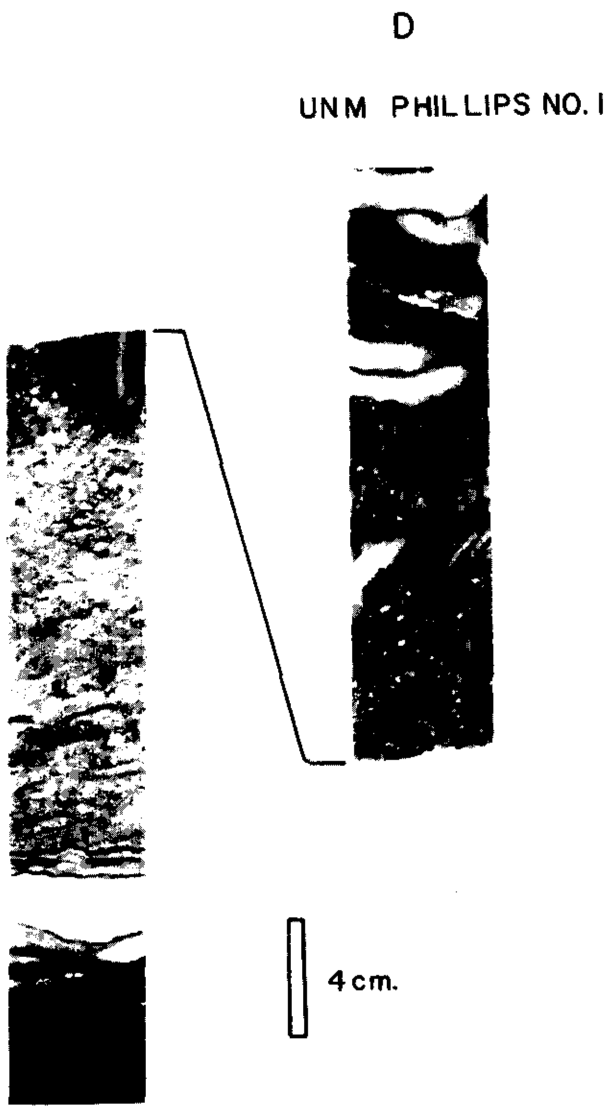

FIGURE 2—DISSOLUTION BRECCIA OVERLAIN BY COLLAPSE BRECCIA IN UNM-PHILLIPS NO. 1 CORE (LOCATION D). Third breccia bed above the base of Halite III, fig. 5.

original salt bed. Hence, the matrix is probably the finely disseminated anhydrite, calcite, and organic matter contained within the original halite laminae, often along microlaminations within halite laminae. As salt is dissolved, the matrix encloses the elongate fragments of larger anhydrite laminae to produce a dense unit of dissolution breccia.

Because we are able to trace the breccia beds to salt layers, we can show that there is an approximate relationship between the thickness of the salt bed and the thickness of the correlative breccia bed. However, because the thickness of the original salt beds at the breccia bed locality (fig. 1, location D) is not known, the exact ratio cannot be determined. The examples available show that one foot (0.3 m) of dissolution breccia is equivalent to between 20 and 30 ft (6 and 9 m) of halite.

Collapse breccias

Many, but not all, beds of dissolution breccia are overlain by a collapse breccia of angular fragments of laminated anhydrite (fig. 2). The angular fragments are fitted together in a tight interlocking pattern with little or no fine-grained anhydrite matrix. The fragments range in size from a few millimeters to blocks of more than 30 cm, with a definite tendency for fragments of similar size to be found together.

An examination of the breccia fragments and their association with the intervening undisturbed layers of laminated anhydrite reveals some information about the probable nature of the collapse process. Beds of collapse breccia, for example, have developed several meters above underlying layers of dissolution breccia. In certain parts of the UNM-Phillips No. 1 core the overlying column of laminated anhydrite fractured. This fracture created a void some distance above a chamber formed by dissolution of salt; and the void, thus created, in turn collapsed to produce a breccia. Hence, removal of a salt layer at depth resulted in a diminishing chain reaction above in which breccia layers form at apparently random positions in overlying anhydrite beds. An almost identical occurrence in connection with collapse associated with salt solution mining has been reported by Dowhan (1976) in which an overlying column of dolomite and sandstone was brecciated at random positions by removal of salt and collapse at depth. Intraformational breccia in the Michigan Basin has also been described by Landes (1959) and appears to be of similar origin.

There is some evidence for lateral movement of breccia blocks and fragments. Large (up to 30 cm) blocks of laminated anhydrite in vertical orientation occur between separated horizontal laminae of anhydrite, indicating that the disturbed block has moved laterally into the void space. Some moderately dipping (30-40°) fractures in the horizontally laminated anhydrite are filled with angular breccia fragments of uniform size, suggesting that the breccia was actually a slurry injected between walls of the separated fracture. Hence, the brecciation process may not have been entirely dry, and fluids may have played a role in the movement of breccia blocks and fragments.

Correlation of dissolution horizons

The feasibility of correlating individual calcite-anhydrite laminae over long distances in the Delaware Basin was demonstrated by Anderson and Kirkland (1966). This same technique can be used to demonstrate that a particular salt bed correlates with a particular layer of dissolution breccia. A comparison of the anhydrite laminae a few centimeters below the lowermost halite bed in the Halite III unit of the Castile Formation (from a Winkler County, Texas, core; fig. 1, locality E) with the equivalent laminae associated with dissolution breccia (from a Culberson County, Texas, core; fig. 1, locality D), shows positively that the overlying halite and dissolution breccia are equivalent (fig. 3, correlation A). The equivalency of halite and dissolution breccia is also verified by correlating individual anhydrite laminae within a 2-ft-thick (0.6 m) anhydrite bed within a halite bed in the lower part of Halite III (fig. 4, laminae correlation B). These two localities are separated by 70 mi (113 km) and are on nearly opposite sides of the Delaware Basin. The visual quality of the correlation is not as good as correlations over shorter distances, but the individual laminae indicated in the illustrations are unquestionably equivalent. Correlation is further verified by the thickness and spacing of other beds of halite and dissolution breccia within the Halite III Member of the Castile Formation as depicted in cores and acoustical logs (fig. 5).

Development of dissolution

The laminae and log correlations described above demonstrate that even the thinnest salt beds deposited in the eastern part of the Delaware Basin once extended far to the west and probably extended over most of the basin. This means that it is relatively safe to assume that the departures from full stratigraphic section observed in acoustical logs are the result of removal of original salt beds, rather than the result of facies changes within the basin. This conclusion makes possible an assessment of the development of salt dissolution for certain areas of the basin. It also makes it possible to trace dissolution horizons to specific dissolution features in the basin and to clarify their relationship to salt removal.

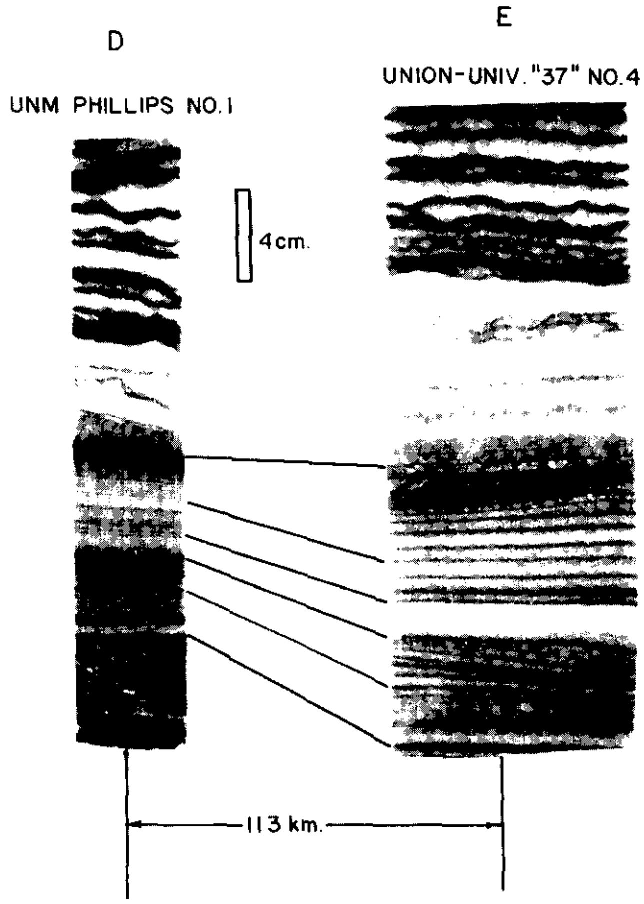

FIGURE 3—Laminae correlation A at the base of Halite III (fig. 5).

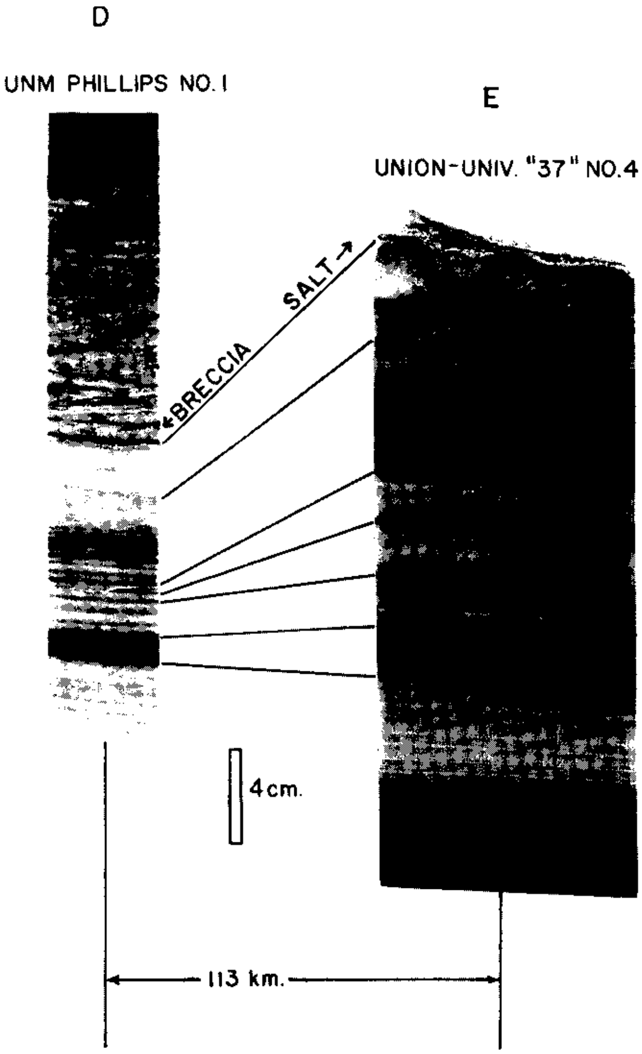

FIGURE 4—LAMINAE CORRELATION B FROM THIN ANHYDRITE BED WITHIN LOWER HALITE BED OF HALITE III (FIG. 5). Note that salt and breccia beds are correlative and that salt precipitation occurred at approximately the same time at both localities.

Big Sinks dissolution depression

Malley and Huffington (1953) mapped a number of large-scale dissolution depressions in the Delaware Basin that are filled with thick sequences of Cenozoic fill. Most of these depressions lie above the inner edge of the reef along the eastern margin of the basin (fig. 1). Several of these features, however, occur along the western margin of salt, and one extends from Texas into New Mexico in the vicinity of Big Sinks (fig. 1). An acoustical log across the sharp eastern margin of this depression reveals that salt in the lower part of the Salado and upper part of the Castile Formations has been dissolved to produce the depression (fig. 6). This interpretation is confirmed by comparing structure contours on the top of the overlying Rustler Formation with isopach contours of the salt lying between the Cowden Anhydrite Member and the 136 marker bed of the Salado Formation (lower Salado). Within a distance of a few miles, the 300-ft (91.5 m) salt section has been dissolved and is matched by an equivalent depression in the structure contours of the Rustler Formation (fig. 7). The dissolution depression has developed under an undisturbed layer of salt in the upper and middle Salado Formation and is about 20 mi (32 km) from the western edge of overlying salt. Salt dissolution in this particular depression has been extensive; the dissolution has even extended below the Salado into the lower part of the Castile Formation.

Controls on dissolution

The degree to which the overlying evaporites have been undermined by dissolution suggests certain hydrologic controls on the dissolution process. The large dissolution depressions along the eastern margin of the basin were formed by contact with undersaturated waters moving through the reef system (Hiss, 1975). A similar situation may have prevailed along the western margin of the basin in earlier stages of stripping and dissolution so that the salt horizons adjacent to the reef mass (upper Castile and lowest part of Salado) were preferentially dissolved. However, such a system of contact with reef waters could probably not maintain dissolution for distances in excess of 50 mi (80.5 km) from the reef (site of the Big Sinks depression). Present surface drainage on the top of the salt along the western margin generally follows the north-south flow of the Pecos drainage. A similar direction of flow in the subsurface, perhaps along predisposed horizons within the evaporite body and approximately along the axis of the Balmorhea-Pecos-Loving trough of Hiss (1975), would be needed to remove the volume of salt now occupied by the depressions.

Development of breccias

As the subsurface dissolution advanced eastward within the evaporites, it left behind a relatively undisturbed, albeit fractured, sequence of laminated anhydrite with various amounts of collapse breccia above dissolution horizons and within the overlying anhydrite beds. The presence of deep and extensive solution features such as the Big Sinks dissolution depression suggests that the eastward advance of the dissolution front in the subsurface was not always a gradual and uniform process. An advancing front of salt dissolution will develop caverns and tunnels at the leading edge and outliers of salt at the trailing edge. In the Delaware Basin, gradual dissolution along a leading edge apparently caused little disturbance to the overlying sequence in most of the basin, other than a minor wave of brecciation translated upward into the overlying anhydrite beds. The collapse of a pre-front cavern, however, can be expected to be a rather sudden event. Such a collapsing cavern could be expected to develop a brecciated chimney (pipe) above the cavern, and, if the height and size of the cavern were sufficient, this type of brecciation would be translated to the surface to produce a sink. Collapse breccias similar to those observed in breccia pipes have been observed forming in collapsing salt cavities produced by solution mining (Jaron, 1970). The development of such collapse structures, or clusters of collapse structures, may have been precursors to the development of large dissolution depressions such as the Big Sinks depression.

Breccia pipes and masses are a fairly common feature in evaporites. Landes (1959) described a trans-formational breccia on Mackinac Island within the Michigan Basin and attributed it to salt dissolution at depth. Similar structures were reported in Permian rocks of Oklahoma (Myers, 1962). Breccia pipes and collapse structures were described in the Delaware Basin by Vine (1960, 1976), and breccia is associated with some limestone buttes (Castile Formation) described by Kirkland and Evans (1976) on the Gypsum Plain of the Delaware Basin west of the present dissolution margin. The breccia pipes and smaller collapse structures of the Delaware Basin may have facilitated the advance of a dissolution front, thereby accelerating salt removal and collapse at depth.

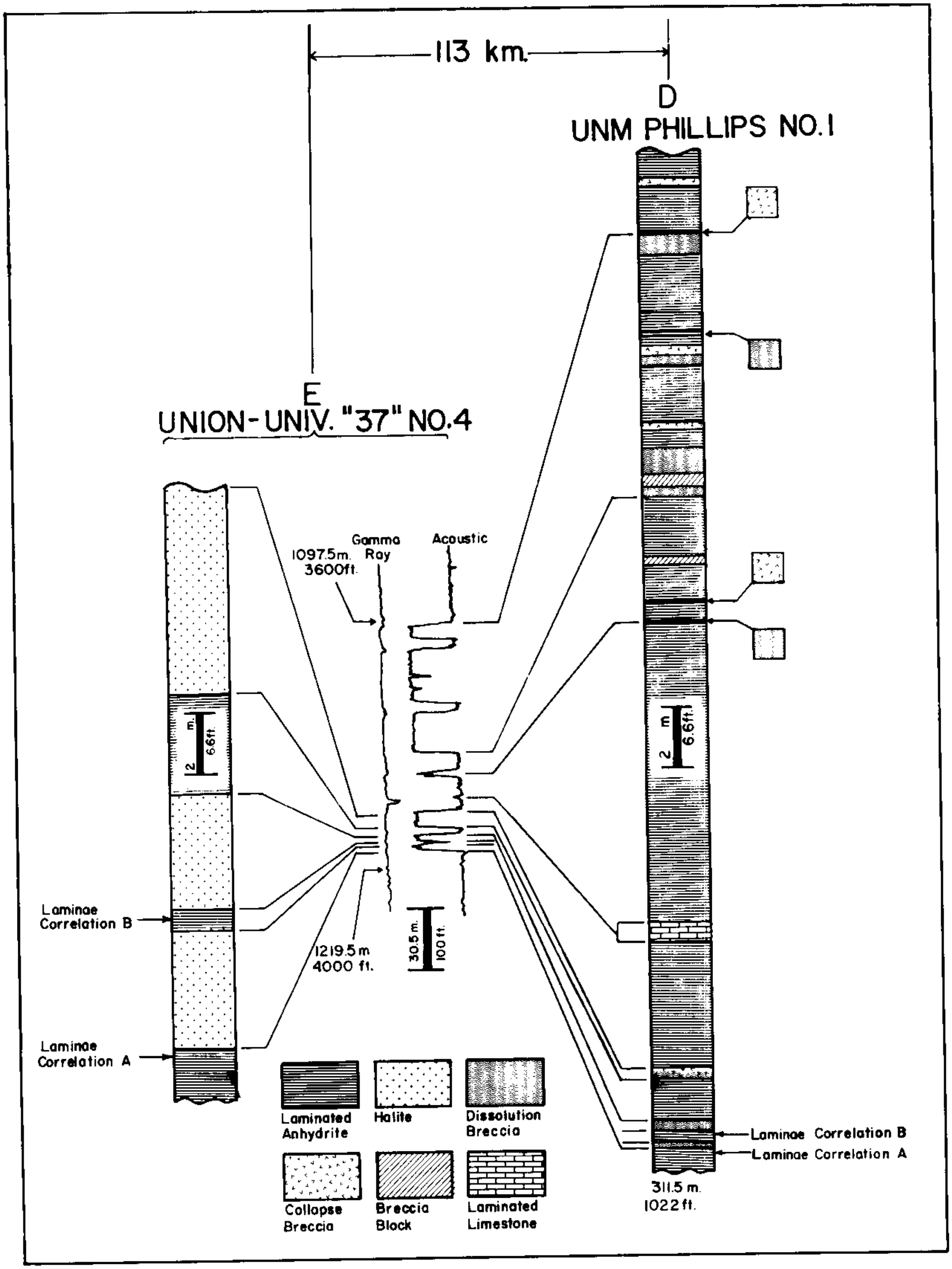

FIGURE 5—Correlation diagram showing stratigraphic locations of laminae correlations A and B and correlation of breccia beds in Halite III member between UNM-Phillips No. 1 core and acoustical log and core from Union-Univ. "37" No. 4. Note that collapse breccia may occur without an immediately underlying dissolution breccia.

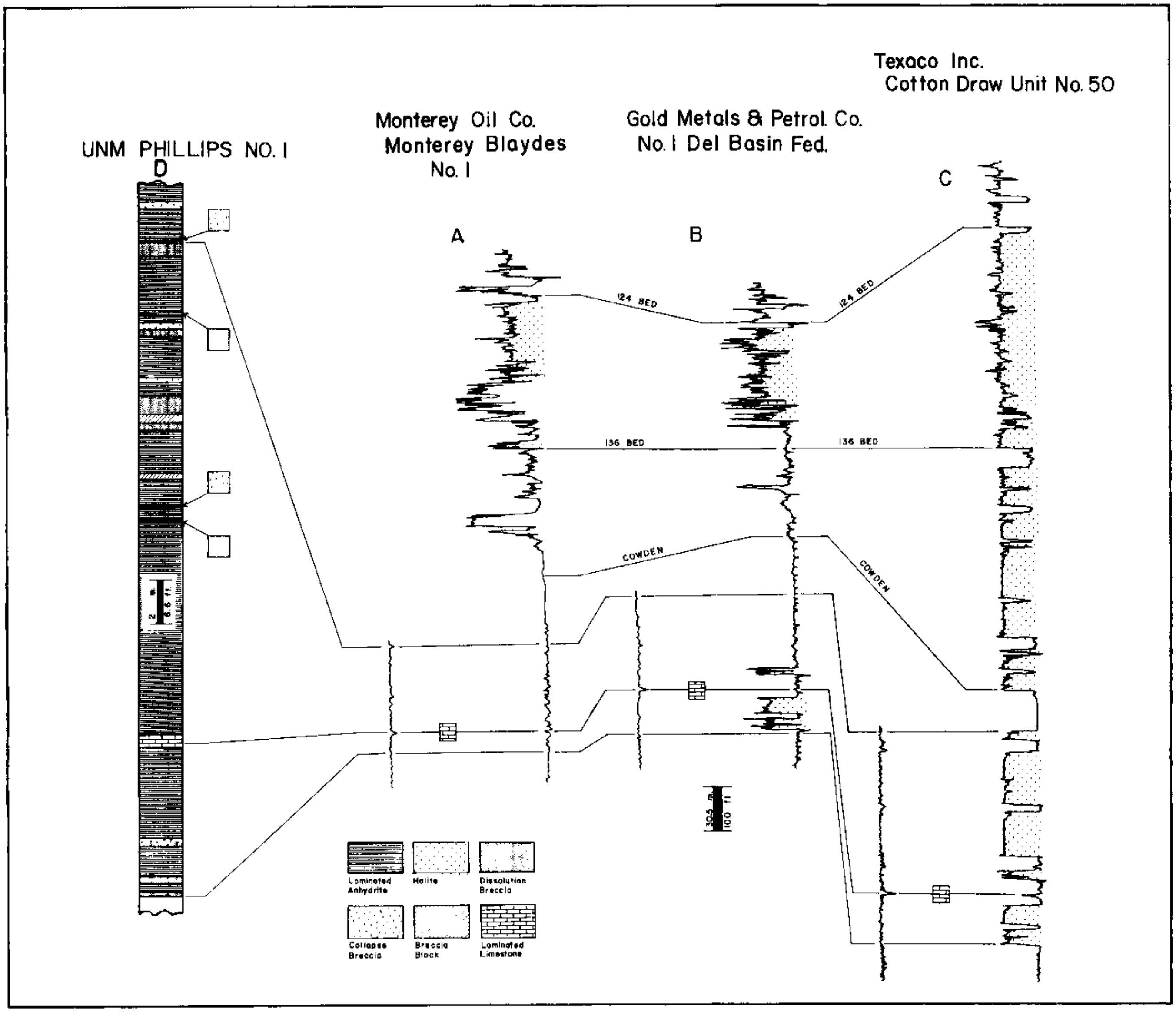

FIGURE 6—CORRELATION DIAGRAM SHOWING DISSOLUTION HORIZONS OF SALT WITHIN BIG SINKS DISSOLUTION DEPRESSION. Locality C is complete salt section. Note that horizon of most active or most complete dissolution is near the Cowden Anhydrite Member (fig. 1). Log on right at each locality is acoustic log; log on left is gamma ray log.

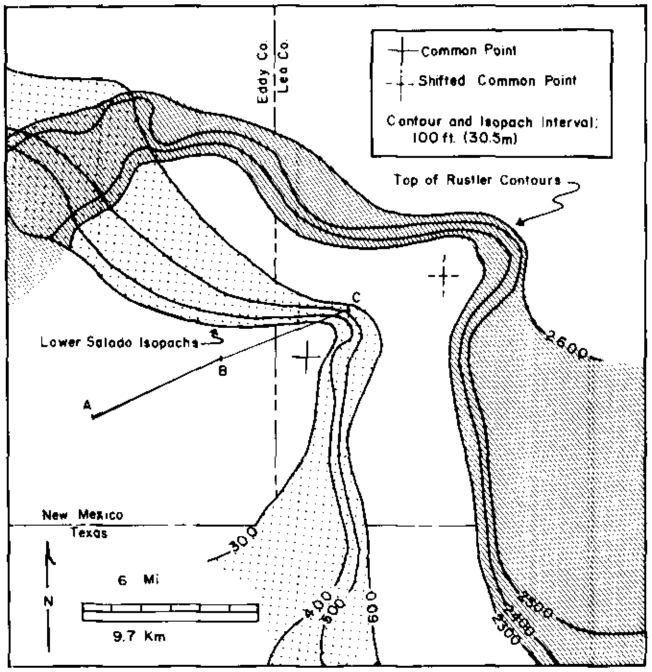

FIGURE 7—Relationship between structure on top of Rustler Formation and removal of salt from the lower part of the Salado Formation. *Note that removal of 300 ft (91 m) of Lower* Salado salt has resulted in approximately the same amount of depression of Rustler contours. Common point of Rustler isopach contours must be shifted southwest to same location as common *point of Salado contours for original placement. Isopach interval* is between the Cowden Anhydrite Member and 136 marker bed; locations shown in fig. 1.

Conclusions

1) Every salt bed recognized on acoustical logs in the eastern side of the Delaware Basin has an equivalent bed of dissolution breccia in the western side of the basin, indicating that all of the western salt-bed margins are dissolutional *rather than depositional.*

2) The dissolution of salt beds proceeded downdip from the western edge of the basin with the preferred dissolution horizons occurring between the Halite III salt of the Castile Formation and the 136 marker bed of the Salado Formation.

3) Downdip dissolution within the body of evaporites has undercut the overlying salt beds for distances in excess of 20 mi (32.4 km), and more extensive dissolution at these same horizons in localized areas resulted in large scale collapse and dissolution features such as the Big Sinks depression.

References

Anderson, R. Y., Dean, W. E., Jr., Kirkland, D. W., and Snider, H. I., 1972, Permian Castile varved evaporite sequence, west Texas, and New Mexico: Geological Society of America, Bull., v. 83, p. 59-86

Anderson, R. Y., and Kirkland, D. W., 1966, *Intrabasin varve correlation:* Geological Society of America, Bull., v. 77, p. 241-255

Dowhan, D. J., 1976, Test drilling to investigate subsidence in bedded salt: Wyandotte, Michigan, Wyandotte Corp., unpub. rept., 13 p.

Hiss, W. L., 1975, *Stratigraphy and ground water hydrology of the* Capitan aquifer, southeastern New Mexico and western Texas: Ph.D. thesis, University of Colorado, 396 p.

Jaron, M. G., 1970, Investigation of solution collapse breccia in mature salt cavities: Third Symposium on Salt, Northern Ohio Geological Society, p. 422-428

Kirkland, D. W., and Anderson, R. Y., 1970, Microfolding in the Castile and Todilto evaporites, Texas and New Mexico: Geological Society of America, Bull., v. 81, p. 3259-3282

Kirkland, D. W., and Evans, R., 1976, Origin of limestone buttes, Gypsum Plain, Culberson County, Texas: American Association of Petroleum Geologists, Bull., v. 60, p. 2005-2018

Landes, K. K., 1959, The Mackinac breccia, *in* Geology of Mackinac Island and Lower and Middle Devonian south of the Straits of Mackinac, F. D. Shelden, ed.: Michigan Basin Geological Society, Guidebook, p. 19-24

Malley, V. C., and Huffington, R. M., 1953, Cenozoic fill and evaporite solution in the Delaware basin, Texas and New Mexico: Geological Society of America, Bull., v. 64, p. 539-545

Myers, A. J., 1962, A fossil sinkhole: Oklahoma Geology Notes, Oklahoma Geological Survey, v. 22, p. 13-15

Vine, J. D., 1960, Recent domal structures in southeastern New Mexico: American Association of Petroleum Geologists, Bull., v. 44, p. 1903-1911

———, 1976, Breccia pipes and burial metamorphism in Permian evaporites of the Delaware Basin, New Mexico (abs.): Geological Society of America, Abstracts with Program, v. 8, p. 1154