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A CLASTIC DEPOSIT WITHIN THE LOWER CASTILE FORMATION, WESTERN DELAWARE BASIN, NEW MEXICO

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ABSTRACT

In the vicinity of CP Hill, about 16 km south-southwest of Whites City, New Mexico, a brecciated sequence in the lower Castile Formation has been examined in detail. Four distinct units associated with the breccia sequence have been defined. Unit A is clast poor, structureless to thinly bedded, and contains kerogen. It occurs only over nodular anhydrite. Unit B is pseudo-bedded, with anhydrite matrix supporting tabular anhydrite clasts. Unit C contains abundant rounded polyclasts and is grain-rich. Unit D is similar to A, but clasts are finer in Unit D. These beds are arranged in vertical sequence and show lateral thinning in an apparent fan shape. The textures, grading, and vertical and lateral relationships suggest this breccia unit was deposited as a subaqueous debris flow.

INTRODUCTION

Submarine fans of gypsum or anhydrite have been reported (Billo, 1986) for the Castile Formation along the northern and eastern margins of the Delaware Basin. Oral tradition among geologists interested in Delaware Basin evaporites includes some mention of exotic blocks or Capitan outliers, but no details or specific facts are known to us regarding these occurrences. We have been investigating the lower Castile from the western part of the Delaware Basin (Fig. 1). We report here our study, based on cores, of the details of a debris flow unit.

We studied cores from 28 boreholes to examine the evidence for dissolution and depositional variations within the Castile. The cores from the area around CP Hill (Fig. 2) are especially pertinent as they provide evidence of a debris flow unit coeval with deposition of the evaporites. We will concentrate on breccia textures and their distribution as evidence of the debris flow process.

The Castile Formation is cited frequently as an example of deep-water evaporites displaying great lateral continuity of beds. Anderson and Kirkland (1966) provided statistical evidence of lamination by lamination correlation of parts of the lower anhydrite of the Castile over a distance of 14 km. Later, Anderson et al. (1972) reported a high degree of correlation of laminae over distances of 113 km. The Castile has also been studied more recently for evidence of deformation (Anderson and Powers, 1978; Borns, this

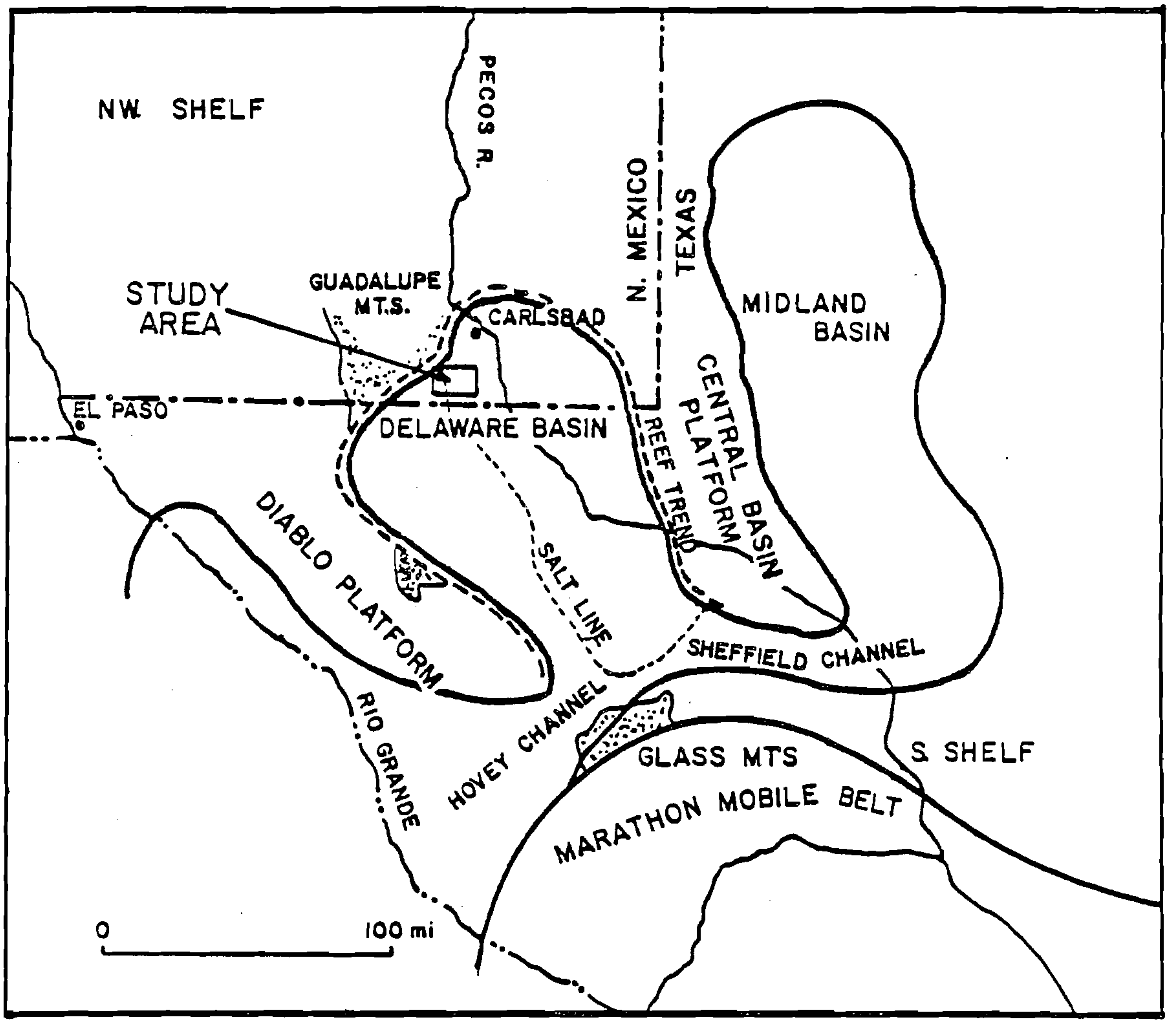

Figure 1: Location Map And Permian Basin Complex Of West Texas And New Mexico (After King, 1948)

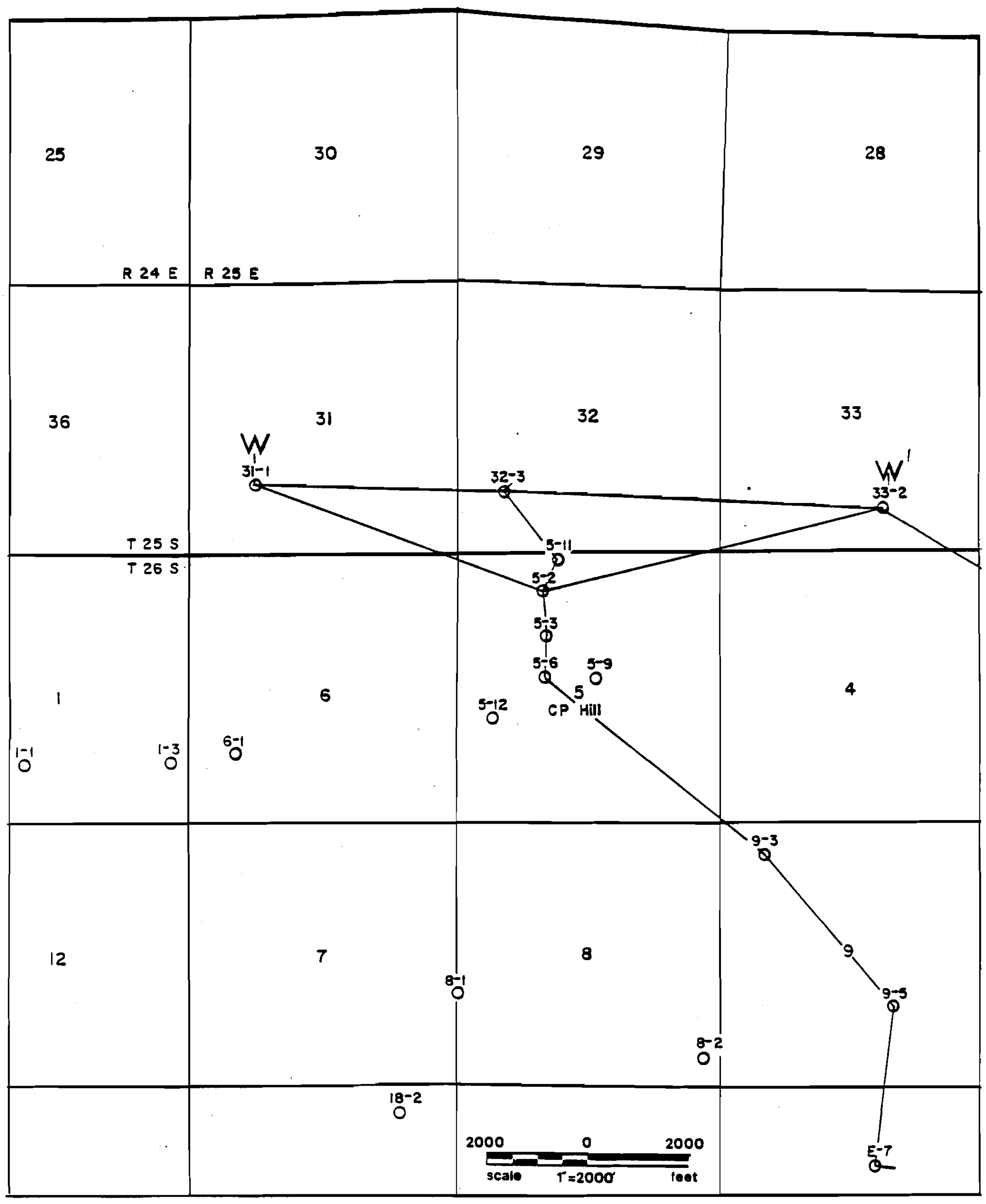

Figure 2. Boreholes and cross-section W-W' (see Figure 3) locations near CP Hill.

volume) and salt dissolution (Anderson, 1978, 1981, 1982; Anderson et al., 1978; Lambert, 1983; Bachman, 1976, 1980, 1984, this volume). The formation provides an excellent opportunity to examine evaporites in detail because of extensive sulfur exploration and production (Smith, 1978; Mussey and Tyree, 1984) and because the formation is penetrated by boreholes for oil and gas exploration/production.

The Castile has been divided stratigraphically by Anderson et al. (1972) into informal members numbered from the base. In the area of study, we identify readily the lower four members: Anhydrite I (AI), Halite I (HI), Anhydrite II (AII), and Halite II (HII). Anhydrite III is not easily separated in this area from either the Salado Formation or from upper members of the Castile as halite is absent. We restrict our study to AI through AII to focus on the debris flow.

METHODS

We initially examined cores by wetting surfaces; basic descriptions of textures and sequences were noted and photographed. Laminated to brecciated intervals from several holes were selected and slabbed using a large diameter slabbing saw (Powers, 1986). Slabs were polished moderately to remove saw marks, and then were described and photographed in more detail. Thin sections of some textures were described and photographed.

Cores from the study area contain intervals near the base of AII that superficially appear featureless. We have found slabbing of these apparently featureless intervals reveals intricate textures of various clasts, matrix, and cement that are loosely termed "breccia." The clasts are mostly identifiable as Castile because they display anhydrite/carbonate laminations. Matrix here includes anhydritic silt and mudstone. Cement from these lower units is anhydrite, or less commonly gypsum, filling fractures or pore space. Breccia textures are extremely obvious in some zones, as those photographed by Anderson and Kirkland (1980). The surface of the core is damaged sufficiently by drilling to render surface description insufficient for parts of our study.

STRATIGRAPHIC RELATIONSHIPS OF BRECCIA UNIT

Within the study area, Halite I thins dramatically from east to west and is absent in the vicinity of CP Hill and westward. The "salt line" (Fig. 1) marks this boundary. In the area where salt disappears, cores contain brecciated material. Based on core analysis and geophysical log examination, Anderson et al. (1978) concluded that breccia and certain log signatures are evidence of dissolution of halite. The breccia described here is a unit that to the east fits between the top of Halite I and base of Anhydrite II and to the west is nominally between Anhydrites I and II where Halite I is absent. In general relationships, it is similar to the lower solution zone reported by Anderson et al. (1978).

Breccia textures at this stratigraphic interval were encountered in 16 core holes and exhibit clear vertical morphological variations that laterally persist. In general, the brecciated series is divisible into six major parts: two contacts and Units A through D.

The rock underlying the lower contac of the breccia units ranges from bedde nodular anhydrite to halite. The lowe contact with the bedded nodular anhydrit is always sharp. It appears that th contact with halite is also sharp, but th halite has been partially dissolved b drilling fluid in many cores.

The cores close to CP Hill demonstrat local stratigraphic differences in th upper part of AI (Fig. 3). Hole 33- contains about 60 m (200 ft) of AI wi eleven conspicuous nodular zones. T contact with HI is preserved. About 30

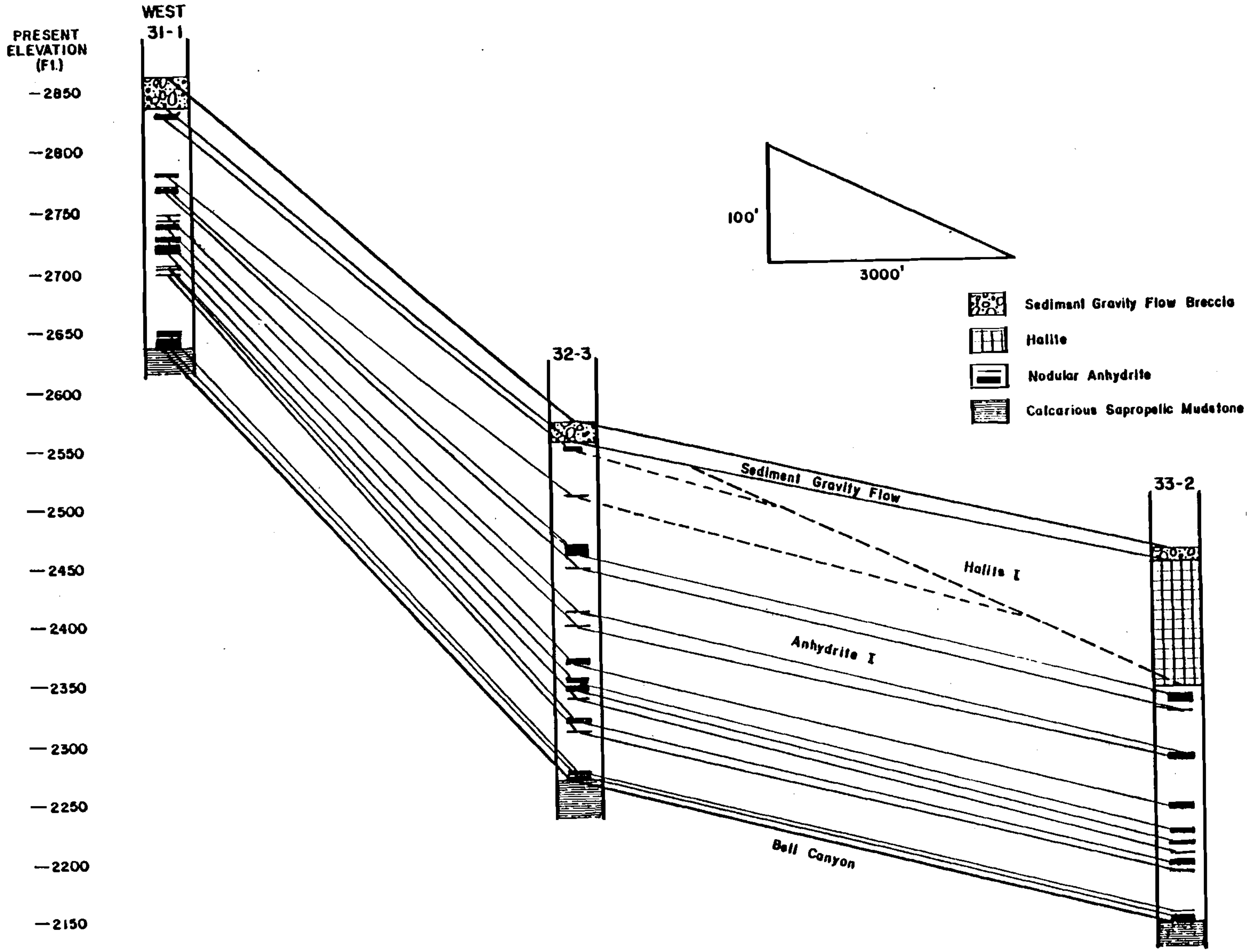

Figure 3 Cross Section W-W'
Nodular Correlations In Thickened Anhydrite I, Hole 32-3

(100 ft) of HI exists, followed by the breccia zone studied here. Hole 32-3, about 2 km (1.3 mi) west of 33-2, displays a section of anhydrite (AI) below the breccia bed about 85 m (280 ft) thick. It appears to include the eleven nodular zones of 33-2 and two additional nodular zones at the top. Further west, core 31-1 displays a section of about 60 m (200 ft) of AI below the breccia with nodular zones that appear to be correlatable with 32-3. The cores show clear stratigraphic variations due to depositional differences, though there may have been some additional modification by the process which formed the breccia bed. This contrasts with the prevailing view of great continuity of individual laminations over distances exceeding 100 km (Anderson et al., 1972).

The upper contact is variable over the study area. In some cores, there appears to be a gradational sequence from breccia into normally laminated Castile anhydrite over very thin intervals. Most cores display a thin cemented crackle breccia that upwards gives way to less fractured to unfractured laminated anhydrite. The maximum thickness of crackle breccia is about 3 m (10 ft).

BRECCIA TEXTURES

Unit A

Within the breccia sequence in these boreholes, the unit at the base is generally moderately dark brown, very fine grained, clast-poor anhydrite. Thickness of Unit A varies up to about 30 cm (12 in.). The unit may be structureless or very thinly bedded. Clasts, when present, are tabular shaped (about 6 mm or less) and float within the matrix. The unit is always present over nodular anhydrite, but is absent over halite.

Yellow, thermally immature kerogen has been isolated from this unit from several holes. No material is recognizable for biostratigraphic analysis.

Unit B

Unit B is a moderately dark brown, psuedo-bedded fine grained anhydrite matrix supporting abundant tabular, light gray anhydrite clasts having an apparent bimodal grain size distribution. We use pseudo-bed because we are still uncertain whether the planar features are multiple internal sedimentary bedding surfaces indicating a number of separate events or, less likely, internal shear planes which operate to transport sediment flows down slope (Hampton, 1972). The pseudo-beds are usually between .5 cm (.2 in.) and 6.25 cm (2.5 in.) thick and may be in stacks of as many as 50. Bed surfaces are always parallel, and typically horizontal, although dips to 20° have been observed.

The matrix-supported clasts are tabular (2.5 to 12.5 mm long) with rounded corners. Some clasts contain a carbonate/anhydrite couplet. They are oriented mainly subparallel to the under- and overlying bed surfaces. Clasts may be sorted into common size fractions within individual pseudo-beds. The clasts may also float without apparent orientation within the thicker beds and unbedded units where sorting is absent. Unit B is a bedded, cemented rubble float breccia (Morrow, 1982).

Unit C

Unit C, often interbedded with B, is a cemented rubble float and pack conglomeratic breccia (Morrow, 1982). Unit C is gray, unbedded, and clast- to matrix-rich. It contains abundant rounded amalgamated polyclasts, unoriented tabular clasts, and rare rounded floating laminated clasts. Rounded polyclasts are composed of matrix-supported tabular clasts with both aligned and random orientation. This grain-rich unit may be either matrix supported or have clasts in grain-to-grain contact. Unit C may exhibit poor and irregular inverse grading with large laminated clasts usually restricted to the upper part. Some unfractured, normally laminated anhydrite units (to 45 cm) occur within Unit C as well as B.

Unit C is characteristically the thickest unit within the breccia, and is about 6 m (20 ft) thick in hole 5-6 at CP Hill.

Unit D

Unit D is similar in character to Unit A. It consists of moderately dark brown, very fine grained, thinly bedded anhydrite ranging in thickness from about 7.5 cm (3 in.) to about 60 cm (2 ft). The units usually have few clasts, though some thin zones of fine tabular silt-sized clasts have been observed. A few rounded gravel-sized laminated clasts appear at the top. In addition, abundant isolated euhedral carbonate rhombs (up to 3.5 mm) float within the dark brown anhydrite.

Within Unit D, thin, laminated carbonate/anhydrite couplets may occur. The upper contact appears in some cores to be gradational into normally laminated Castile anhydrite which may be unfractured or slightly fractured.

TEXTURE RELATIONSHIPS

The breccias that occur in the interval over HI and AI exhibit similarities laterally and vertically suggesting common processes of origin. In addition, the breccia unit as a whole appears stratigraphically confined so that a common origin both in process and time is indicated. We will discuss the vertical and lateral relationships in more detail before describing the processes of formation.

Vertical Sequence

The textural units have been designated alphabetically because of the general vertical sequence of these units and their associated textures. Unit A occurs at the base in the area of the contact with anhydrite. It is overlain by Units B and C often in that order or alternating as units through the middle of the breccia sequence. Unit D tops the sequence before moving into a completely different style of brecciation, the crackle breccias.

Lateral Relationships

The thickness of the breccia unit varies systematically away from a maximum of about 12 m (40 ft) at CP Hill to zero thickness (Fig. 4). In addition, clast size decreases away from the thickest part corresponding to the decrease in thickness of Unit C and number of pseudo-beds within the unit. Unit B dominates away from the thickest portion. Both thickness and pattern of clast sizes suggest a fan-shaped deposit with its source in the vicinity of CP Hill.

ORIGIN AS DEBRIS FLOWS

The breccia unit is interpreted as having been formed as a subaqueous debris flow or series of debris flows. The principal lines of evidence for this conclusion are the rounding of clasts, matrix support of clasts, internal bedding and clast orientation, lateral thickness and clast size trends, and overall shape of the deposit based on isopachs.

Several additional features are important to illustrate the conditions preceding sedimentation of this unit.

Both Bell Canyon Formation and Anhydrite I show apparent structural deviation in the vicinity of CP Hill. For the Bell Canyon, the deviation in trend to the

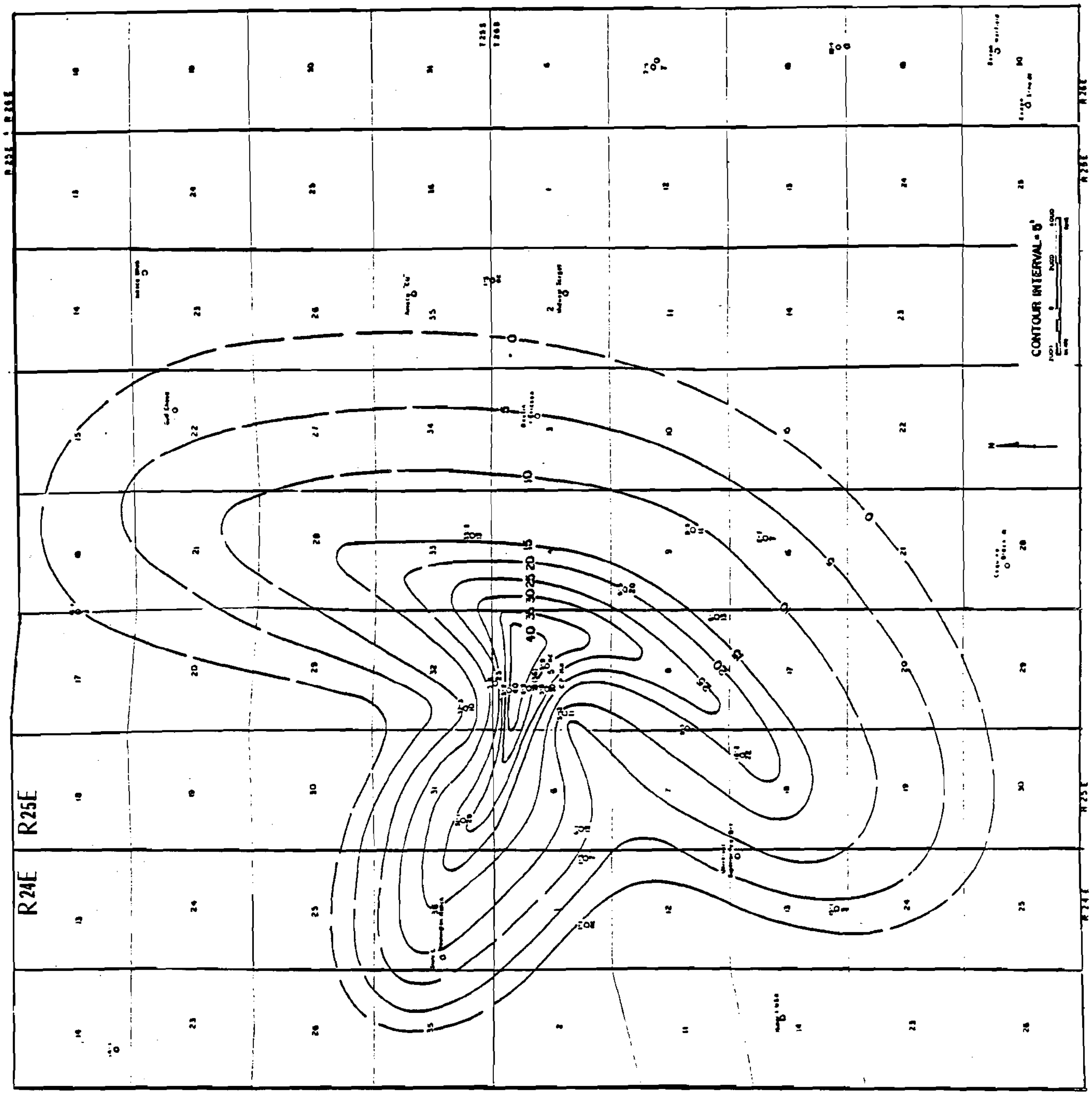

Figure 4. Isopach map of "breccia" unit above Anhydrite I near CP Hill.

southwest from a general north-south strike is consistent with the development of the Huapache Monocline. Halite I thins east to west onto this structural trend as reflected by both thickness and apparent structure on Anhydrite I. Changes in thickness of Anhydrite I and the lack of upper nodular layers to the east suggest the depositional changes were consistent in space with the monocline, and that the monocline was still active during or about the time of AI-HI deposition. Depositional processes, and differences in brine composition and/or depth across this structure, account for the greater anhydrite thickness below the breccia in hole 32-3 compared to that under HI in 33-2 to the east.

DISCUSSION

Dissolution, as a more general alternative mechanism for the formation of evaporite breccias in the western part of the Delaware Basin, has been proposed by Anderson (1978) and explored in several subsequent publications (Anderson et al., 1978; Kirkland and Anderson, 1980; Anderson, 1981, 1982). We are providing a depositional model to account for the features in the vicinity of CP Hill. We are not proposing this model to explain all of the features along the western margin of the Delaware Basin which have been attributed to dissolution. Nevertheless, the data available, prior to this study, for the western margin is principally logs and a few cores, and this is insufficient to exclude a depositional origin for many breccias along the western margin.

The Castile is considered one of the prime examples of deep water evaporite deposits. Among the criteria taken to indicate deep water are (Kendall, 1986):

1. fine laminations of carbonate and sulfate extending over distances of many kilometers;
2. laminated halite, with finely laminated anhydrite and carbonate; and
3. gravity-displaced evaporites.

The debris flow deposit(s) described here fits into a setting in which the first two criteria appear to have been satisfied, and the presence of the debris flow deposit therefore might be taken as evidence that the third criterion is also satisified. In this respect, the often repeated assertion that the Castile formed as a deep-water evaporite would seem to be strengthened.

Dean, Davies, and Anderson (1975) discuss nodular anhydrite within the Castile, and conclude that it is not diagnostic as a shallow-water indicator, partly because the Castile is considered a deep-water evaporite. Within the CP Hill area, the lower anhydrite is thicker where additional nodular anhydrite beds are present; depositional changes are consistent with the change in slope. These changes are also consistent with the disappearance of halite, and strongly suggest that halite was not, at least locally, deposited over this slope and to the west. There is a suggestion then that local brine depth or depth of halite-saturated brine was less than the local change in relief on the Anhydrite I substrate. Among the pieces of evidence that need to be considered in this discussion is the limited amount of bromine in the Castile (Holser, 1966; Adams, 1969), indicating the brine may not have all resulted from marine water evaporation. We will continue to examine evidence and relative merits of the evidence for the concept of deep-water versus shallow-water deposition of the Castile along the western margin of the Delaware Basin.

The crackle breccias which occur above the main bedded or pseudo-bedded breccia units are consistent with downwarping of a rigid beam (AII). The downwarping is considered due to overburden and loss of partial support from below. Two possible mechanisms for loss of support are dissolution and compaction of the underlying debris flow deposit. A combination of the two are possible as well. We do not yet have specific data favoring or opposing either hypothesis.

CONCLUSIONS

A unit of intraformational clasts within the lower Castile near the western margin of the Delaware Basin exhibits clast rounding, bedding, clast orientation and grading, and a fan-shaped distribution that is generally consistent with a model as a subaqueous debris flow or series of flows. Internal units display common textural features that can be mapped within the fan. This depositional model for this deposit contrasts with a more general model of dissolution of evaporites considered to be the origin of breccia textures in the same stratigraphic interval along the broader western basin margin.

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