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DIAGENESIS OF A MIXED ARENITE PETROFACIES, LOBO FORMATION (TERTIARY), SOUTHWESTERN NEW MEXICO

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Abstract—The Lobo sandstones are divisible into four petrofacies based on framework composition: (1) sedarenite, (2) arkose, (3) volcanic arenite and (4) mixed arenite. The mixed arenite, a hybrid of the other petrofacies end members, is composed of subequal amounts of quartz (43%), feldspar (25%) and lithic fragments (32%). Limonite, smectite and calcite are the principal authigenic products found in the mixed arenite with calcite predominant. The mixed arenite is also a hybrid among petrofacies in terms of its diagenetic constituents. It is more closely aligned, both in terms of grain types and diagenetic components, to the sedarenite and volcanic arenite. These compositional relations suggest a strong influence of starting grain composition on diagenesis. Moreover, despite considerable diagenetic modification, the provenance imprint associated with sandstones of the Lobo has clearly not been significantly diminished.

INTRODUCTION

The Lobo Formation of southwestern New Mexico is a coarse, siliciclastic-dominated interval with a wide range of sandstone composition types (Mack and Clemons, 1988). The interval is both geographically and stratigraphically restricted and, therefore, ideal for assessing the influence of framework grain composition on authigenic product type and distribution.

The purpose of this paper is to concentrate on a mixed arenite petrofacies representing a hybrid among three sandstone compositional end members. The main objectives are: (1) compare the framework composition of the mixed arenite petrofacies to other sandstone composition types, (2) describe cements and alteration products present in the mixed arenite, (3) discuss timing and origin of authigenic product types and (4) compare the kinds and distributions of authigenic products in the mixed arenite to those of end member petrofacies. A total of 78 thin sections from five stratigraphic sections form the data base for this study.

BACKGROUND

The Lobo Formation is present in the Cooke's Range and Florida Mountains of southwestern New Mexico (Mack and Clemons, 1988) (Fig. 1). It is now generally accepted that the Lobo is primarily Tertiary in age with a clast composition reflecting contributions from sedimentary, volcanic and crystalline basement terranes (Lemley, 1982; Mack et al., 1983; Seager and Mack, 1986; Russo and James, 1986).

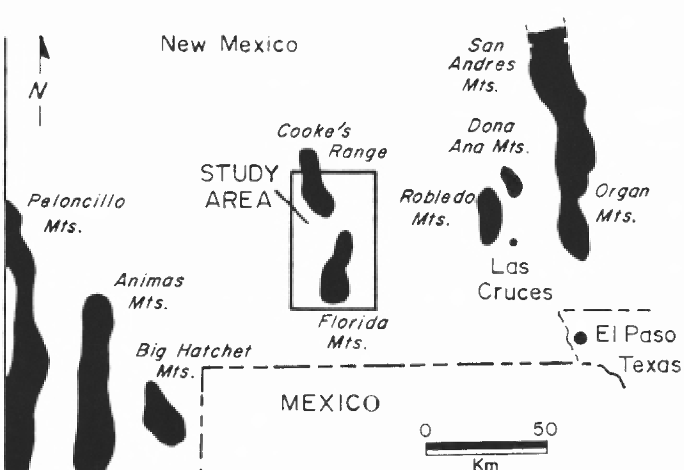

FIGURE 1. Index map of southwestern New Mexico.

The Lobo is interpreted as being deposited in response to Laramide deformation (Lemley, 1982; Brown and Clemons, 1983; Seager and Mack, 1986). Deposition was in alluvial fan-fluvial and lacustrine environments in intra-uplift and uplift-adjacent basins associated with the Laramide Burro uplift (Mack et al., 1983; Seager and Mack, 1986; Mack and Clemons, this guidebook). The interval is about 200 m thick in the northern Florida Mountains and 400 m north of the Laramide Burro uplift in the Cooke's Range (Seager and Mack, 1986).

The close geographic distribution, probable similar maximum burial depths (estimated at 2–3 km; see Seager and Mack, 1986, fig. 6) and likely high heat flow conditions since Lobo deposition (Reiter et al., 1975 for present; Clemons, 1982, common Tertiary igneous activity) for these two basins suggest similar burial histories at least in terms of probable maximum experienced temperatures. As a first approximation the maximum temperatures experienced by the Lobo were probably on the order of 90–110°C.

FRAMEWORK GRAIN COMPOSITION OF SANDSTONE PETROFACIES

Based on framework grain composition sandstones are divisible into four petrofacies: (1) sedarenite, (2) arkose, (3) volcanic arenite and (4) mixed arenite (Mack et al., 1983; Seager and Mack, 1986; Russo and James, 1986). The mixed arenite petrofacies is the focus of this study, especially as to how it compares compositionally (framework and authigenic products) to the other sandstone framework types.

The mixed arenite consists of subequal proportions of quartz, feldspar and lithic fragments ($Q_{43}F_{25}L_{32}$) (Fig. 2). The lithic fragments present are primarily volcanic rock fragments of felsic to intermediate composition. There are also admixtures of quartzofeldspathic, carbonate, sandstone-shale and chert grain types. In terms of the feldspar content, subequal amounts of plagioclase and K-feldspar typify this petrofacies (Fig. 2).

From a framework composition standpoint, the mixed arenite is a hybrid of components from each of the three other petrofacies. On a Q-F-L plot the mixed arenite is most similar to the sedarenite petrofacies (Fig. 2). A Qm-Plag-K-spar plot depicts the mixed arenite as intermediate between the sedarenite and arkose. On the basis of rock fragment types it is most compositionally similar to the volcanic arenite petrofacies. A natural question to address is—To what extent have these starting framework components influenced and been modified by diagentic processes? In order to answer this question, first one must consider the types and distributions of authigenic products present in the mixed arenite.

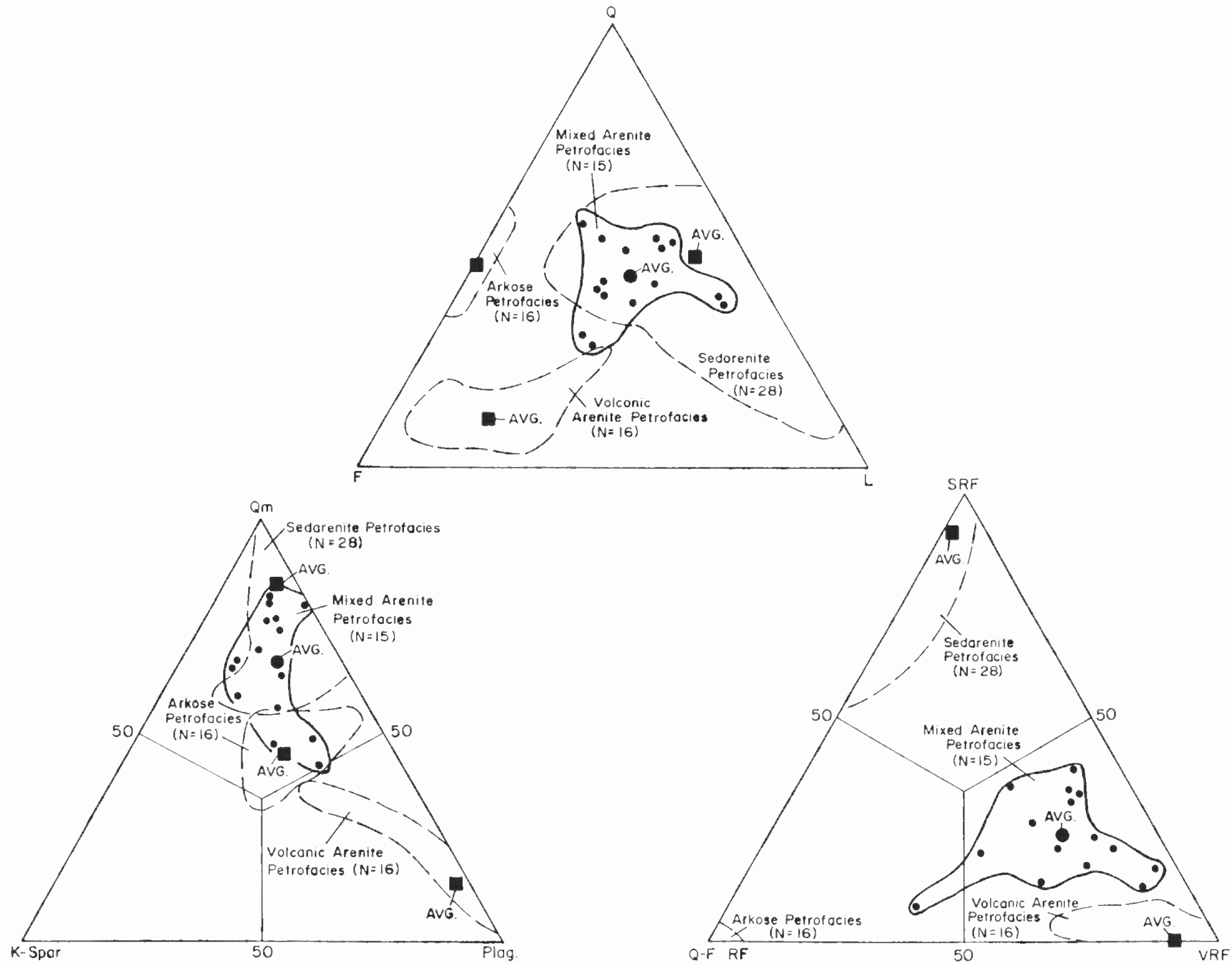

FIGURE 2. Framework composition triangular diagram plots. Average values and field boundaries shown for sedarenite, arkose and volcanic arenite petrofacies. Average values, data points and field boundaries indicated for the mixed arenite petrofacies. Q = total quartz, F = plagioclase + K-spar, L = total lithic fragments, SRF = sedimentary rock fragments, Q-F RFs = quartzofeldspathic rock fragments, VRF = volcanic rock fragments, QM = monocrystalline quartz, K-spar = orthoclase + microcline + sanidine, Plag = plagioclase.

AUTHIGENIC PRODUCTS

Description

Three major authigenic products dominate the mixed arenite petrofacies. They are: (1) limonite, (2) smectite and (3) calcite. In addition, a rare probable mixed layer illite/smectite clay is present.

Limonite

Limonite is defined by Deer et al. (1975) as hydrated oxides of iron with usually poor crystalline character, where real identity is uncertain. In this study all iron oxides-hydroxides, including those with definite crystalline character, are grouped as the mineraloid limonite. Limonite is not only a very common authigenic product in the mixed arenite but is ubiquitous throughout the Lobo.

The limonite is both pore lining and pore occluding in character. The degree of development of pore-lining cement ranges form continuous grain coats (5–20 microns thick) present on all grain types in a thin section to discontinuous, sporadic occurrences. Limonite can partially replace grains commonly along mineral cleavage. It is interspersed in calcite cement as an alteration product in some thin sections. Limonite also concentrates in and around Fe-bearing silicate minerals such as biotite and amphibole. This cement/alteration product ranges from amorphous, finely disseminated particles to 5–20 micron diameter circular concentrations. In reflected light limonite may be black or dark brown through yellow, orange and red in color.

Calcite

All thin sections examined in the mixed arenite petrofacies contain calcite as a cement. It is as high as 42% of the whole rock in one sample. Calcite's habit ranges from rare, isolated patches to a very well developed, extensive occluding cement. It is rarely a discontinuous, isolated pore-lining component.

Texturally the calcite of the mixed arenite ranges from micrite to spar. Rarely, the calcite is poikilitic. Where it occurs as larger spar or poikilitic crystals, it is often twinned. Moreover, larger calcite crystals usually form a blocky, anhedral mosaic. It can replace most all framework grain types, especially carbonate rock fragments, volcanic rock fragments, chert and feldspar. The original detrital grain boundaries of many carbonate fragments have been obliterated by this replacement process resulting in oversized patches of calcite cement. As has been previously noted, irregular clumps of limonite are disseminated within the calcite. Elsewhere, micritic calcite is intermixed with limonite-dominated concentrations.

Phyllosilicate cements

Two phyllosilicate cements are present, smectite and a mixed layer illite-smectite. The smectite clay is a common component in most samples, while the mixed layer clay is extremely rare.

Smectite appears very finely disseminated with a random orientation and yellowish to light brownish birefringence. It occurs mainly as a pore-filling cement and grain replacement/alteration product. When present as a pore filling, it usually occupies an open framework. It partially replaces volcanic rock fragments and plagioclase grain types. XRD and SEM analyses elsewhere in the Lobo have determined the smectite is a Ca-montmorillonite.

A rare, discontinuous pore-lining illite/smectite is also present as a phyllosilicate constituent in the mixed arenite petrofacies. Its yellowish birefringence and potassium and calcium content (EDX analysis) are the basis for identification.

DISCUSSION

Based on textural relations there is considerable overlap in timing of diagenetic product distribution in the mixed arenite petrofacies (Fig. 3). The rare, illite-smectite pore-lining component is early in the paragenetic sequence and pre-dates all but a minor portion of the limonite alteration product. Limonite haloes around Fe-bearing silicate grains likewise formed very early. Walker (1967) has illustrated that limonite can be produced early in the burial history of a sandstone due to alteration of such Fe-bearing silicate grains. No clear soil-related textures appear to be typical of early authigenic components, with the exception of possible clay skin textures, associated with the illite/smectite pore-lining cement (clay skins; FitzPatrick, 1984).

Calcite formation overlaps with early limonite production and forms the bulk of the cement in the petrofacies. Textural relations between intergrowths of calcite and smectite suggest a complicated formative history. Clearly in some samples calcite predates smectite while the opposite is the case elsewhere. Finally, an often finely disseminated calcite-limonite mix clearly post-dates (based on textural relations) all other pure end member diagenetic components (note also late limonite patches). This authigenic product may be the result of uplift and exposure of the Lobo to meteoric water influence near the end of its burial history. The open framework associated with calcite and limonite cements may indicate early precipitation or later textural rearrangement due to the force of crystallization process (Dapples, 1971).

COMPARISON OF DIAGENETIC CONSTITUENTS AMONG SANDSTONE FRAMEWORK TYPES

The role of grain types in influencing sandstone diagenesis has been addressed in a variety of summary papers, usually focusing on one particular end member compositional type. For instance the common diagenetic effects associated with quartz-dominated sandstones have been recently delineated by Sibley and Blatt (1976), Odom et al. (1979), Houseknecht (1984) and James et al. (1986). The diagenesis of more feldspar-rich sandstone types is characterized by Helmold and van de Kamp (1984) and Walker (1984). Studies such as Davies et al. (1979) and Mathisen (1984) have concentrated on those sandstones rich in volcanic rock fragments. Only rarely have such studies been able to evaluate more than one sandstone framework compositional type with accompanying constraints on geographic and stratigraphic distribution.

The major diagenetic components found distributed among all petrofacies in the Lobo are listed in Table 1. The sedarenite petrofacies has the smallest number of authigenic components and appears to have undergone the simplest diagenetic history. It is characterized by calcite cement (96%) with a significantly smaller amount of limonite (4%). The arkose petrofacies is dominated by siliceous cements to include an impure siliceous component (86%; mixture of microquartz, limonite and clay), microquartz (4%), chalcedony (4%) and quartz overgrowths (2%). Other diagenetic constituents are laumontite (3%), feldspar overgrowths (trace), calcite (1%) and sphene (trace). The volcanic arenite contains subequal portions of smectite (23%), calcite (23%) and heulandite (20%) as diagenetic components. Limonite (15%), laumontite (11%) and illite/smectite (7%) cements are also common. The mixed arenite suite is lacking in siliceous authigenic products and feldspar overgrowths (Table 1). Samples for this petrofacies range from calcite-dominated to a high proportion of clays plus limonite.

As previously stated the framework composition of the mixed arenite has similiarities in common with all other petrofacies (Fig. 2). In terms of grain composition, is is most closely aligned with the sedarenite on quartz content, and the volcanic arenite based on rock fragments. It has the least clast compositional affinity with the arkose petrofacies. However, it does partially overlap with the arkose on a monocrystalline quartz-K-feldspar-plagioclase triangular plot (Fig. 2).

The distribution of authigenic products in the mixed arenite reflects framework composition and can generally be related to diagenetic components in other petrofacies (Figs. 4 and 5). The mixed arenite is most similar to the sedarenite, slightly less so to the volcanic-clast-rich sandstones and has least affinity to the arkose in terms of calcite cement content. The same holds true for the siliceous authigenic content with only the arkose having more than a trace of this component. Feldspar overgrowths are negligible in all petrofacies. In the total clay + limonite + zeolite distribution there are similarities of the mixed suite with all other petrofacies. However, this is somewhat misleading (Fig. 5). The mixed arenite, sedarenite and, to a lesser extent, volcanic-arenite distributions in this category are due to limonite ± clay (volcanic arenite also has a major zeolite component). The distribution of these components in the arkose is dominated by zeolites.

There is a definite, predictable relation between framework composition and diagenetic component distribution within petrofacies. Be-

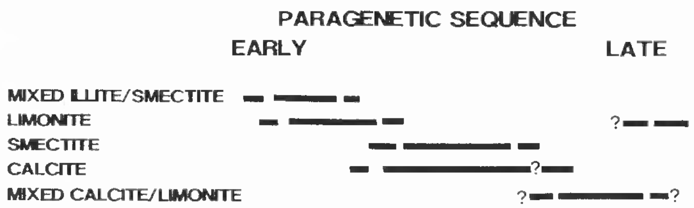

FIGURE 3. Paragenetic sequence, mixed arenite petrofacies.

TABLE 1. Distribution of authigenic constituents for all petrofacies. * denotes greater than 10% of total authigenic components for a particular petrofacies.

ALTERATION PRODUCTS	MIXED ARENITE	SEDARENITE	VOLCANIC ARENITE	ARKOSE
Limonite	X	X	X*	--
Calcite	X*	X*	X*	X
Smectite	X*	--	X*	--
Mixed I/S	X	--	X	--
Impure Siliceous	--	--	--	X*
Chalcedony	--	--	--	X
Microquartz	--	--	--	X
Quartz Ovgths.	--	--	--	X
Laumontite	--	--	X*	X
Heulandite	--	--	X*	--
Feld. Ovgths.	--	--	X	X
Sphene	--	--	--	X
Barite	--	--	X	--

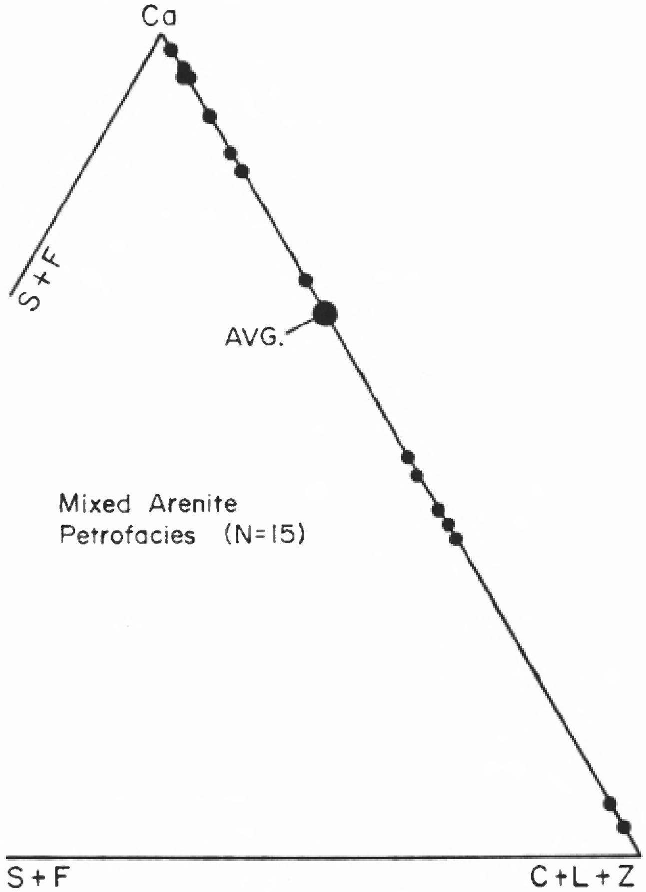

FIGURE 4. Distribution of authigenic constituents in the mixed arenite petrofacies. Ca = calcite, S+F = total siliceous components and feldspar overgrowths, C+L+Z = clay minerals, limonite and zeolites.

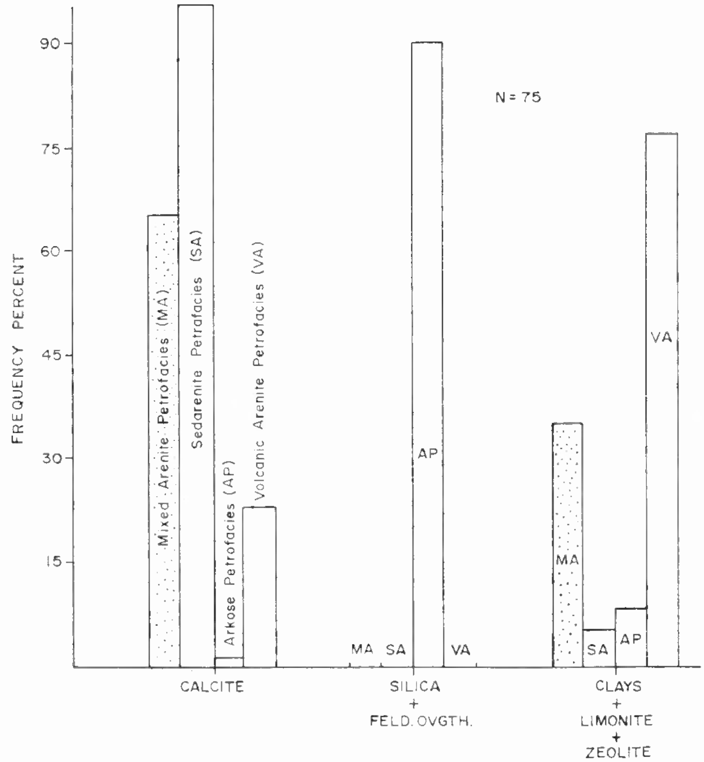

FIGURE 5. Histogram comparing petrofacies as to diagenetic components and their abundances.

cause of the rather restricted geographic and stratigraphic distribution of data, it seems unlikely major differences in basin history could have been a significant factor influencing authigenic constituents. The role of starting framework grain types in sandstones appears to have been paramount in influencing the distribution of cements and alteration products. Moreover, the provenance imprint, despite burial diagenesis, has clearly not been significantly reduced. This is an especially important point as two recently published articles suggest that diagenesis may commonly destroy provenance signatures in sandstones (Blatt, 1985; Shanmugam, 1985).

CONCLUSIONS

1. The mixed arenite is intermediate in clast composition in comparison with the sedarenite, arkose and volcanic arenite petrofacies. Overall, it has closest affinities to the sedarenite and volcanic arenite.

2. There are three major authigenic products associated with the mixed arenite: limonite, smectite and calcite. A rare, pore-lining illite-smectite is also present.

3. The distribution of authigenic constituents in the mixed arenite is intermediate in composition to those of end member petrofacies. It generally has closer similarities to the sedarenite and volcanic arenite, suggesting a major influence of framework composition on diagenesis.

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Dry wash near Howell's Wells, Little Hatchet Mountains. View is S45°E. Howell's Wells is marked by the windmill and cottonwood trees in distance. Arroyo cut in southwest-dipping Mojado Formation. Southeast end of Howell's Ridge on left composed of reef and suprareef members of U-Bar Formation conformable beneath Mojado. Low ridge on right composed mostly of Hell-to-Finish Formation. Prominent shrub on gravel bars in wash is burrobrush. Hachita Valley, Apache Hills and Sierra Rica are visible in distance beyond Howell's Wells. Camera station is in NE1/4 NW1/4, sec. 24, T28S, R16W. Altitude about 1478 m. W. Lambert photograph No. 87L40. 24 July 1987, 4:13 p.m., MDT.