



Stratigraphy and sedimentology of the Morrison Formation (Jurassic), Ojito Spring Quadrangle, Sandoval County, New Mexico: A preliminary discussion

Gary A. Flesch

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STRATIGRAPHY AND SEDIMENTOLOGY OF THE MORRISON FORMATION (JURASSIC), OJITO SPRING QUADRANGLE, SANDOVAL COUNTY, NEW MEXICO: A PRELIMINARY DISCUSSION

by

GARY A. FLESC¹

Cities Service Oil Company

Exploration and Production Research Laboratory

Tulsa, Oklahoma 74150

INTRODUCTION

A study of the Morrison Formation was undertaken to describe the stratigraphy and sedimentology of the individual members (i.e., Recapture Shale, Westwater Canyon Sandstone, Brushy Basin Shale, and "Jackpile" Sandstone) and to interpret their environments of deposition in the Ojito Spring Quadrangle, Sandoval County, New Mexico (Fig. 1). Preliminary results of that study are discussed herein.

Field methods included mapping the surface distribution of individual Morrison members and the measurement and description of closely spaced (< 1 mile) stratigraphic sections of the members, especially the Westwater Canyon Sandstone (14 measured sections) and the "Jackpile Sandstone" (15 measured sections). Emphasis was placed on determination of member and sedimentary unit geometry, description of primary physical sedimentary and biogenic (trace fossil) structures, measurement of cross-stratification dip direction (azimuth), amount of dip and cross-strata set thickness, and

collection of samples for detailed textural and compositional analyses, including x-ray analysis of clay mineral composition. Support for field work was generously given by The Society of Sigma Xi, the Mineral Division of Getty Oil Company, Hydro Nuclear Corporation, and especially Ranchers Exploration and Development Company. This support is gratefully acknowledged. A brief discussion of basic references for the Morrison Formation can be found in Woodward and Schumacher (1973). References especially pertinent to this study include Craig (1955), McKee and others (1956), Moench and Schlee (1961 and 1967), Kelley (1963) and Woodward and Schumacher (1973). Stratification and cross-stratification terms in this report are those defined by McKee and Weir (1953). Orientation data (cross-stratification readings) were computed using vector analysis (Curry, 1956) to determine palocurrent directions.

STRATIGRAPHY AND SEDIMENTOLOGY

The Morrison Formation (Upper Jurassic) is approximately 750 feet thick in the Ojito Spring Quadrangle and consists (in ascending order) of four lithologically distinct and mappable members: Recapture Shale, Westwater Canyon Sandstone, Brushy Basin Shale, and "Jackpile Sandstone" (of economic usage) (see Table I).

The Morrison Formation as a whole is composed of interbedded and intertongued subarkosic to arkosic arenities (54.5%) and variegated, montmorillonitic claystones (45%), with thin micrite beds a very minor component (0.5%). Unit geometry, especially for sandstone bodies, varies from laterally continuous units of subequal thickness to discontinuous lenses.

Internal sedimentary structures of the sandstones are dominantly medium and large scale trough (festoon) and wedge cross-stratification. In addition, scour and fill structures, planar (?) cross-stratification, parallel laminations, parting lineation, small scale ripples, mudcracks, trace fossils and distorted laminations (rare only) may be common locally.

Recapture Shale Member

The Recapture Shale outcrops in a narrow roughly north-south trending belt in the eastern half of the study area. Approximately 250 feet of Recapture is present. The basal contact of the Recapture is arbitrarily placed at the top of the highest gypsum bed in the Summerville Formation.

The Recapture consists of red-brown and gray-green, montmorillonitic claystones (54%), interbedded with yellow-tan

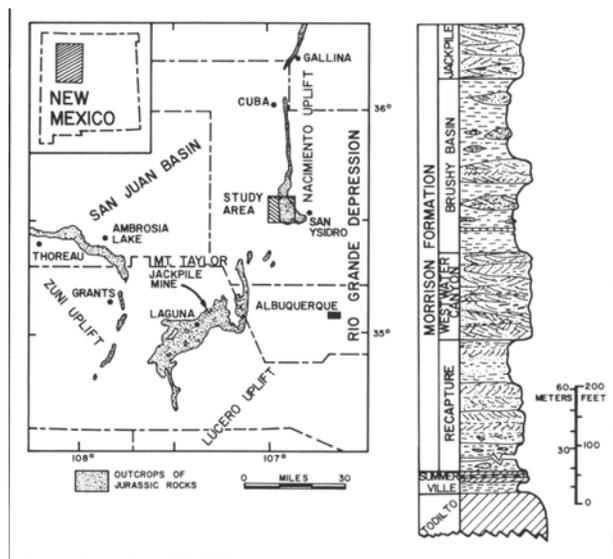


Figure 1. Location map, modified from Woodward and Schumacher, 1973; and composite, representative stratigraphic column of the Morrison Formation, Ojito Spring 7½-minute Quadrangle, Sandoval County, New Mexico.

¹ Formerly University of New Mexico, Department of Geology.

Table 1. Nomenclature used for rock units along southern and eastern edge of San Juan Basin, New Mexico, from Woodward and Schumacher (1973). Nomenclature column for this report is to scale for the Morrison and Summerville Formations.

Renick, 1931	Baker, Dane and Reeside, 1936, 1947	Kelley and Wood, 1946	Wood and Northrop, 1946	Freeman and Hilpert, 1956	Woodward and Schumacher, 1973	This Report
Dakota(?) Sandstone	Cretaceous	Dakota(?) Sandstone	Dakota Sandstone	Dakota Sandstone	Dakota Formation	Dakota Formation
Morrison Formation upper member lower member	Morrison Formation Shale member Sandstone member	Morrison Formation Variegated shale member White sandstone member Brown and buff sandstone member Buff shale member	Morrison Formation unnamed member	Morrison Formation Brushy Basin Member Westwater Canyon Member Recapture Member Bluff Sandstone Summerville Formation	Morrison Formation upper member Brushy Basin Member Westwater Canyon Member lower member	Morrison Formation "Jackpile" Sandstone Brushy Basin Member Westwater Canyon Member Recapture Member
Todilto Formation	Todilto limestone	Todilto gypsum member	Todilto gypsum member	Todilto Limestone	Todilto Formation	Summerville Fm. Todilto Formation

chalky-gray and gray-tan, generally subarkosic arcrites (46%) (Fig. 3A). The Recapture can be subdivided into four subunits, based upon varying abundances of claystone and sandstone and upon the type of sandstone present. Sandstones commonly are friable, with only locally more resistant sandstone lenses occurring. Sandstone mean grain size ranges from 2.3 to 2.9 phi (fine sand) and averages 2.6 phi; grain size standard deviation ranges from 0.5 to 0.6 phi (moderately well sorted).

The geometry of claystone and friable sandstone units in the Recapture is generally continuous with subequal thicknesses. Some intertonguing with the overlying Westwater Canyon occurs in the northern portion of the study area. Local, discontinuous lenses of resistant sandstone comprise approximately 10% of the total sandstone (Fig. 3B).

Internal structures are prevalent, although often poorly preserved, especially in friable sandstones; medium to occasionally large scale, generally moderately dipping trough cross-stratification and parallel lamination (in claystones) are the most common. In addition, planar(?) cross-stratification, parallel laminations, parting lineation, and minor scour and fill (associated with discontinuous sandstone lenses) are present. Trace fossils are found locally along surfaces of slightly resistant platy beds. These consist of linear, small diameter (< 1/4 inch), horizontal unornamented burrows.

Westwater Canyon Sandstone Member

The Westwater Canyon Sandstone outcrops along a narrow, roughly north-south trending belt in the eastern half of the study area. The thickness of the Westwater Canyon varies (see Fig. 6) from 110 to 160 feet where one sandstone unit is present in the southern half of the area (see Fig. 2A and 2D), to 65 to 225 feet (125 feet average) of interbedded sandstone and claystone units (stacked sandstone units) in the northern half (see Fig. 2B and 2C). A partial third dimensional view of the Westwater Canyon was obtained in Cucho Arroyo where 40 feet of the lower sandstone unit is present. Exploration logs (gamma) viewed from wells in the general area indicate similar stratigraphic relationships exist in the subsurface (see fig. 6 of Hazlett and Kreek, 1963). The lower contact of the Westwater Canyon is placed at the base of the first, fairly thick, subarkosic, semi-resistant ledge of sandstone. Interfingering of basal, discontinuous Westwater Canyon sandstone units with Recapture fine friable sandstone and claystone units exists in the northern part of the study area. The surface of the lower contact is slightly undulatory with local scouring.

The Westwater Canyon consists of resistant yellowish to tan, iron oxide stained, subarkosic to arkosic arenities (70-96%) and minor interbedded and intertongued non-resistant claystones (4-30%). Sandstone mean grain size ranges

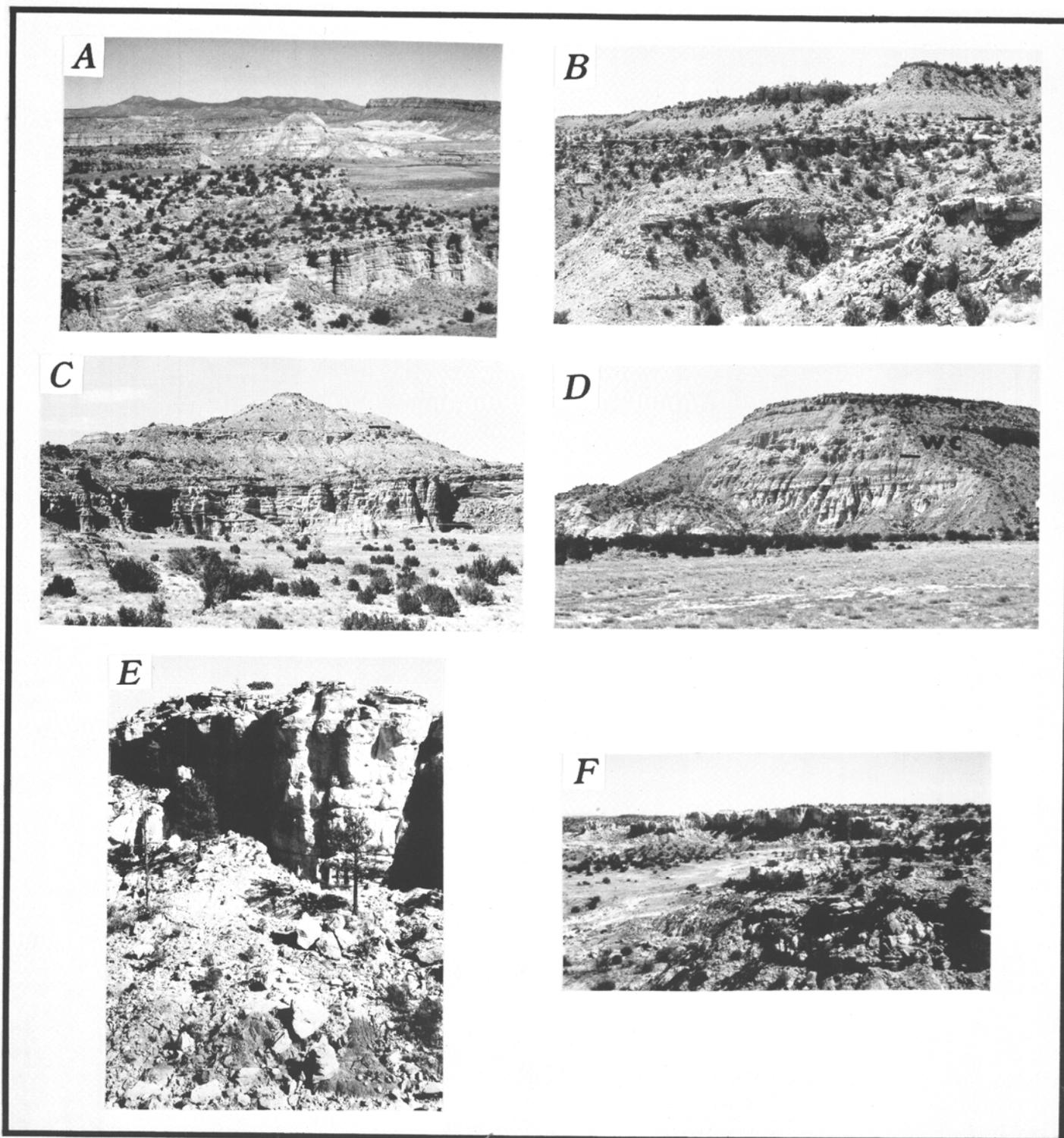


Figure 2. Westwater Canyon, Brushy Basin and "Jackpile" Members: A, Foreground—ledge of Westwater Canyon; above—south side of Cucho Mesa (see Fig. 2D) with variegated Recapture (base), resistant Westwater Canyon ledge (middle); and slope and thin sands of the Brushy Basin (upper); distance—Red Mesa (right) and Pyrito Peak of the Sierra Nacimiento (left); view north; B, Resistant sandstone units of the Westwater Canyon and Brushy Basin (above hatch-mark); interfingering Recapture (non-resistant) with first and second ledge, and Brushy Basin claystone below upper ledge; view south; C, Power Line Road section, with Westwater Canyon and Brushy Basin (above hatch-mark); interfingering of Brushy Basin claystone occurs below the middle ledge (at the hatch-mark); uppermost resistant sandstone contains fossil logs of Figure 5E; D, East face of Cucho Mesa consisting of variegated claystone and sandstone units of the Recapture (base), Westwater Canyon sandstone (marked WC) and Brushy Basin claystone and thin sandstone units (top); E, Reference section of the "Jackpile" sandstone, with underlying Brushy Basin claystone, and thin (2 feet) resistant beds of basal Dakota Formation (top); F, Outcrop of "Jackpile" sandstone overlying non-resistant Brushy Basin claystones; thin layer of Dakota forms the top of the ledge.

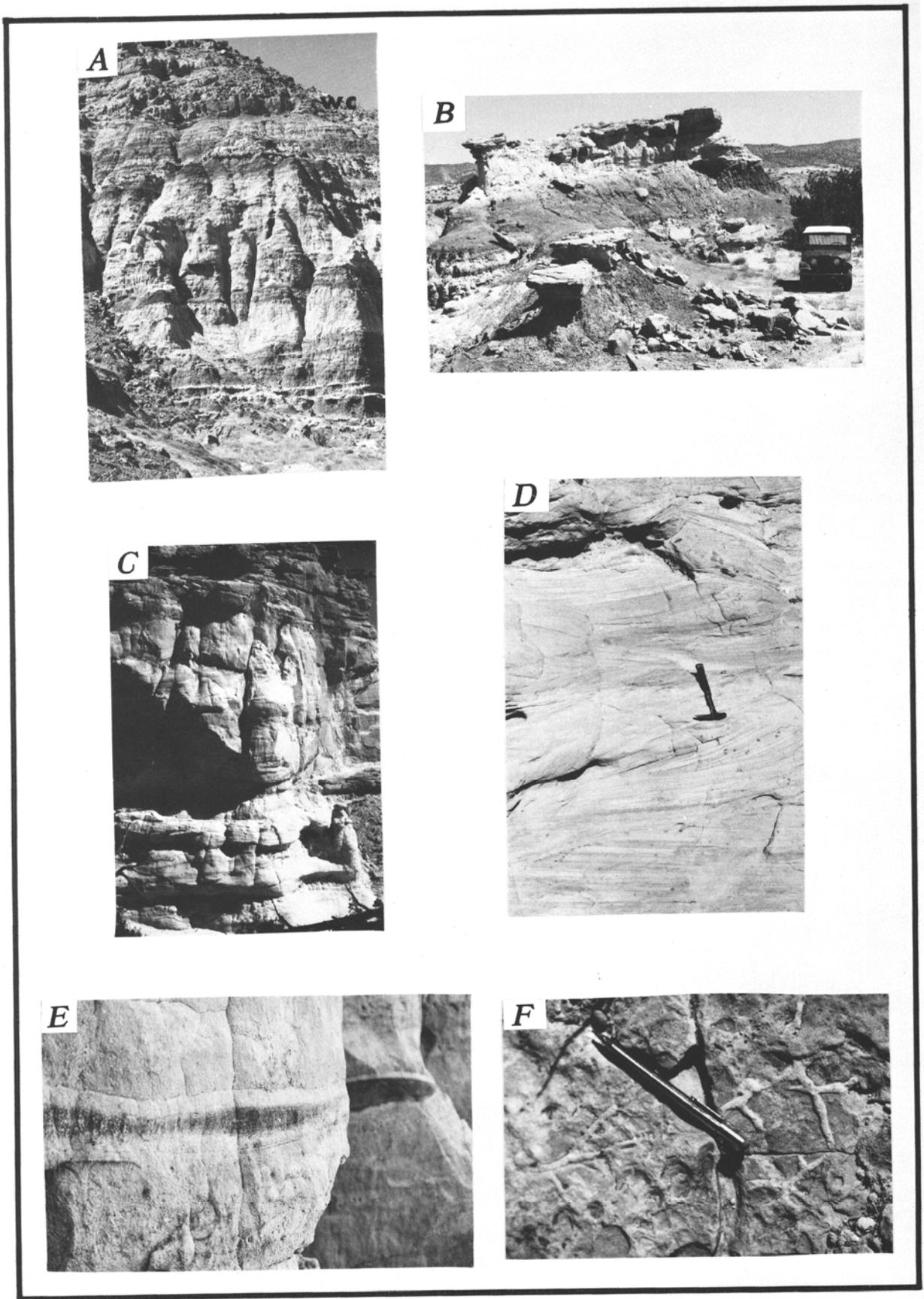


Figure 3.

from 0 to 3.0 phi and averages 2.1 phi (fine sand); grain size standard deviation ranges from 0.4 to 1.0 phi and averages 0.6 phi (moderately well sorted).

The geometry of Westwater Canyon sandstones (Fig. 6) consists of a main continuous, lower unit with varying thickness and a main, upper, discontinuous unit present in only the northern half of the study area. Occasionally, highly discontinuous sandstone units are also present below the main lower unit in the northern half of the study area. This relationship can be clearly demonstrated by walking along the Westwater Canyon outcrop trend.

Internal structures are extremely well preserved and plentiful (Fig. 4), with medium and large scale troughs and wedge sets especially well developed. All other structures, including planar cross-stratification, scour and fill, ripples, parting lineation, and parallel bedding are minor constituents (approximately 10% of total structures present).

Cross-stratification dips are generally moderate to steep (10-25°). The vector resultant calculated from dip azimuth resultants for the upper and lower Westwater Canyon sandstone units together is N 82° E with a standard deviation of 91°, indicating paleocurrent stream flow to the east. Minor components to the south, southeast, southwest and northwest are also present at some localities.

Trace fossils (burrows) are sparse overall, but locally abundant in the Westwater Canyon (Fig. 4E and 4F). These consist of medium diameter (3/8 inch) burrows that are slightly curved with smooth surfaces and horizontal to vertical orientations to bedding (Fig. 4E). Only one locality contained the long vertical, medium diameter (3/8 inch), iron oxide stained, "Skolithus" type burrow. Morrison Formation trace fossils probably record the burrowing activity of insects (C. T. Siemers, personal communication, 1973; Stanley and Fagerstrom, 1973).

Brushy Basin Shale Member

The Brushy Basin Shale outcrops in a roughly north-south trending belt, 1-1/2 miles wide, in the east-central portion of the study area. Approximately 200-300 feet of Brushy Basin is present and is topographically expressed as a broad slope. The basal contact is arbitrarily placed at the top of the uppermost resistant, continuous to moderately continuous sandstone ledge typical of the Westwater Canyon. Intertonguing of these two members occurs in outcrop in the northern half of the area (Fig. 2B and 2C).

The Brushy Basin consists of gray-green and red-brown, montmorillonitic claystone (69%), yellow to tan, iron oxide stained, well indurated arkosic arenites (29%), which contain conglomerate seams and clay galls, thin brown-gray micrite beds (2%), and trace amounts of red-brown, very thin, dense volcanic ash(?) beds (Fig. 5A). No persistent marker-beds, such as bentonites, were found in the interval. The average

mean grain size is 1.8 phi (medium sandstone); however, gravel to silt size grains are present; the coarser size fraction is generally found above scoured surfaces. Grain size sorting varies from moderate to moderately well sorted.

The geometry of the abundant claystone units can best be described as "blanket-like," since they are laterally uniform and continuous, and of equal to subequal thickness. Intertonguing occurs with the upper Westwater Canyon in the northern portion of the area. Discontinuous, resistant sandstone units occur at varying stratigraphic horizons throughout the Brushy Basin (see Figs. 6 and 5C) and are often found capping mesas in the area (Fig. 2B, 2C and 2D). The thin micrite beds are only locally continuous (Fig. 5A).

Internal structures are abundant, consisting of medium scale wedge and trough cross-stratification (Fig. 5B), some planar cross-bedding (Fig. 5C), scour and fill, and graded bedding. Claystones are laminated and occasionally exhibit mud-cracks. Cross-stratification dips are moderate to steep (10-30°) and set thicknesses range from 1 to 4 feet. Calculation of the vector resultant from dip azimuth readings generally yields a north-east, east, or southeast current flow direction. Subsurface data is needed to check these values with the actual trends of the channels.

Fossils were sparse; however, petrified wood (Fig. 5E) is present in channel sandstone units, and a dinosaur bone (Fig. 5F) and bone fragments were found in the Brushy Basin outside the study area. No trace fossils were observed.

"Jackpile Sandstone"

The "Jackpile Sandstone" (of economic usage) outcrops along a narrow, north-south trending belt across the center of the study area, and has been mapped as a separate unit in the Morrison Formation (Fig. 2F). Ruetschilling (1973) and Woodward and Schumacher (1973) have also commented on the "Jackpile" in the San Ysidro area. I have reviewed subsurface logs between Laguna and the study area and have found a persistent sandstone unit in the same stratigraphic position of the "Jackpile" in outcrop; Saucier (this Guidebook) clearly demonstrates this relationship. Cuttings examined from uranium exploration wells drilled on the L-Bar Ranch in Valencia County include sandstone samples lithologically identical to published descriptions of "Jackpile" sandstones (see Moench and Schlee, 1967; and Flesch and Wilson, this Guidebook).

I believe it is advantageous to recognize the "Jackpile Sandstone" as a formal member of the Morrison Formation. A reference section is designated for this study area (Fig. 2E, and section 19 of Fig. 7); however, the type locality for the "Jackpile" should appropriately be at the Jackpile mine. Hopefully, this will be done in the very near future in a formal publication by workers intimately associated with the "Jackpile" in that area.

Figure 3. Recapture and "Jackpile" Members: A, Close-up of the Recapture exposed at the base of Cucho Mesa consisting of variegated claystone and five friable sandstone units with small lenses of more resistant sandstones (local channels); Westwater Canyon (WC) overlying; B, Discontinuous sandstone lense (local channel) in the Recapture, overlying non-resistant montmorillonitic claystone; C, Medium-scale trough cross-bedding with well developed large trough at the top of the sequence "Jackpile"; D, Well developed medium-scale trough cross-bedding common to the "Jack pile" sandstone; E, Thin lense of non-radioactive, presumed carbonaceous material (humate?) present 77 feet above the base of the "Jackpile" reference section of Figure 2E; F, Trace fossils preserved on the top bedding surface of the "Jack pile" sandstone; Dakota basal sandstone and carbonaceous shales directly overlie this but have been eroded away.

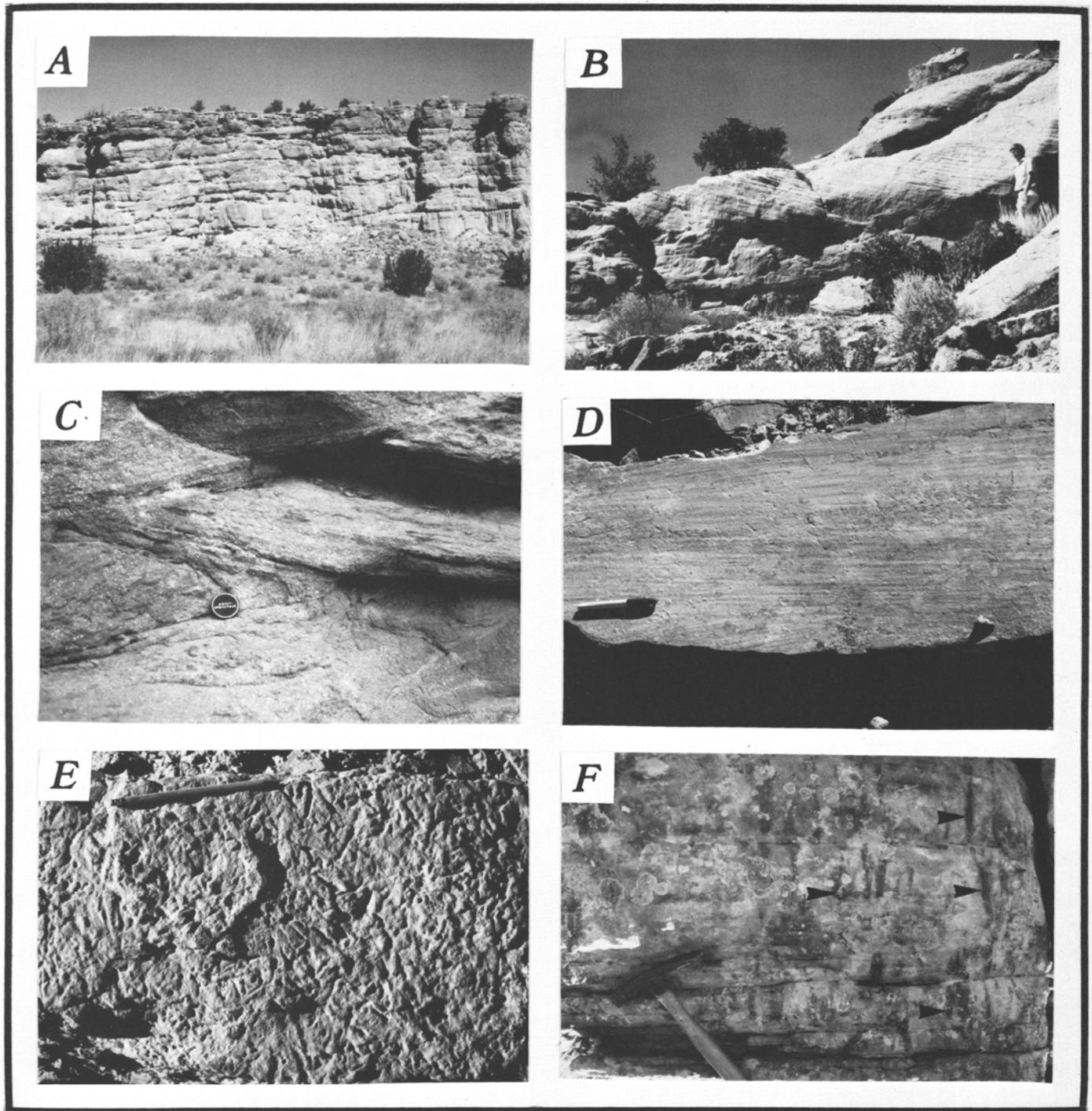


Figure 4. Westwater Canyon Member: A, Closeup of Westwater Canyon ledge shown in Figure 2A; numerous medium-scale troughs within the sandstone unit, defined by claystone partings along bedding and cross-bedding surfaces (ledge is approximately 50 feet thick); B, Large-scale trough cross-bed in the upper Westwater Canyon sandstone unit in the northern end of the study area (See Fig. 2B); C, Well developed medium-scale trough cross-bedding common to the Westwater Canyon; D, Parting lineation structures, Westwater Canyon; E, Trace fossils like these are locally abundant, and may represent burrowing activity of insects; F, Long vertical "Skolithus type" burrow tubes found only at one locality (may represent insect activity within channel).

The outcrop thickness of the "Jackpile" varies from 23 to 90 feet and averages about 50 feet. The lower contact of the "Jackpile" is placed at the base of the distinctive "whitish," semi-resistant, highly cross-stratified sandstone ledge (Fig. 2E and 2F); locally, scouring or intertonguing with the Brushy Basin occurs. The "Jackpile" is unconformably overlain by the

Dakota Formation (Upper Cretaceous) in the study area.

The "Jackpile" consists of yellow to chalky-gray subarkosic arenites, (generally 90-97%), with minor conglomerate seams, clay galls and iron nodules, carbonaceous material, and inter-

bedded gray-green claystone (generally 3-10%). Section 16 (Fig. 7), however, consists of more claystone (56%) than sandstone (44%). Sandstone mean grain size generally ranges from 1.0 to 2.9 phi (medium to fine sand), with some coarser fraction occasionally present (up to -1.0 phi); the average mean grain size is 2.0 phi (fine sand). Grain size standard deviation ranges from 0.4 to 0.7 phi averages 0.6 phi (moderately well sorted).

The overall geometry of the "Jackpile Sandstone" is illustrated in Figure 7. The unit is laterally continuous but of unequal thickness, and is intertongued with claystone units at several localities.

Internal sedimentary structures are well preserved and typically consist of medium to large scale, moderately dipping trough and wedge cross-stratification (Fig. 2C and 2D). All other structures, including planar cross-stratification, scour and fill, parting lineation, ripples, parallel bedding and distorted laminations (rare) are minor constituents. Thin lenses of non-radioactive structureless carbonaceous material (humate?) and lignitic wood fragments were occasionally present (Fig. 2E).

Cross-stratification dips were generally moderate to steep (10-25°). The composite vector resultant calculated from dip azimuth resultants for each of the measured localities is N 66° E with a standard deviation of 129° (based on 182 dip azimuth measurements from 16 stations). Vector resultants at individual localities may indicate flow to the south, southwest, or west.

Trace fossils (burrows) were occasionally observed. They consist of small diameter non-descript burrows similar to those described from the Recapture, and of locally abundant bedding plane burrows. This second type is found only along the uppermost surface of the "Jackpile" (Fig. 3F) and appears similar to Upper Cretaceous marine burrows, probably representing the burrowing activity of shallow marine organisms during initial Dakota deposition.

PALEOCURRENTS

Paleocurrent directions for the Morrison Formation, in particular the Westwater Canyon Sandstone and "Jackpile Sandstone", were determined by computing vector resultants from dip azimuth measurements collected systematically through the vertical sequence from closely spaced stations (exact localities are listed in Table 2), using the equations of Curray (1956). Measurements were taken from planar (tabular), trough (festoon), and wedge cross-stratification sets. Directions of parting lineation were also measured. Vector resultants computed for each station were given equal importance in computing the final resultant for the Westwater Canyon and "Jackpile".

The Westwater Canyon vector resultant of N 82° E and standard deviation of 91° is based upon a total of 331 dip azimuth readings from 13 stations (Table 2). Not all localities have this trend; minor components to the south, southeast, southwest and northwest are also present.

The "Jackpile" has a vector resultant of N 66° E with a standard deviation of 129° (based upon 182 dip azimuth readings from 16 stations, Table 2). Subordinate components to the south, southwest and west occur at some localities.

Recapture readings generally are similar to those of the Westwater Canyon, while Brushy Basin channel sandstones were deposited by generally northeast, east and southwest

flowing currents.

The generally eastward current flow of the Westwater Canyon and "Jackpile" should be considered tentative until these results can be compared with findings in adjacent areas where these units outcrop, and until the geometry of the sandstone units can be determined from subsurface and surface correlations.

The standard deviations of 91 and 129 degrees and subordinate components may be due to several factors. Minor flow components (such as point bars or minor channels) oriented at various angles to the main current flow would result in considerable variation. Also, variation might result from the inability to obtain the actual trough axis directions of some cross-strata or to identify asymmetrical trough filling (Dott, 1973) due to the lack of a three-dimensional view. It should also be noted that planar and trough cross-strata themselves reveal inherent dispersion of some degree (as discussed by Meckel, 1967; and Michelson and Dott, 1973).

DEPOSITIONAL ENVIRONMENTS

Regional stratigraphic studies and paleogeographic reconstructions of the Morrison Formation by previous investigators enables a detailed study of a small area to be meaningful by supplying a framework in which to relate one's interpretations. The studies of Craig and others (1955, especially figs. 22 and 28) and McKee and others (1956, pl. 7 for Interval D and cross-section pl. 8 and pl. 9, fig. 5) are especially notable. By studying the stratigraphy and sedimentology of individual members of the Morrison, changes through time of the depositional environments may be interpreted. There are no previously published accounts of environmental interpretations for the Morrison Formation in the San Ysidro area.

Numerous earlier workers have concluded that the Morrison Formation in New Mexico was deposited primarily in a continental fluvial environment, with streams flowing to the north or northeast from a source area in west-central New Mexico, south of Gallup (Craig and others, 1955; McKee and others, 1956; Harshbarger and others, 1957). In addition, Craig and others (1955) and Keller (1962) indicate that the limestone and some of the claystone of the Brushy Basin may have been deposited in a lacustrine environment. Tanner (1968, and this Guidebook) has suggested a shallow lake environment for deposition of the thin sandstones in the lower part of the Morrison in Rio Arriba County, New Mexico.

The following interpretations of member depositional environments is based upon comparison of unit lithologies and texture, external geometry, and internal sedimentary structures. Supplemental data from the literature is included, when available, to interpret possible regional relationships. Recent alluvial depositional models of Allen (1965, especially figs. 35 and 36) were compared to the field data to enable interpretation of depositional environments. Generalizations concerning current flow regime are based upon comparison of sedimentary structures with plate I of Harms and Fahnestock (1965).

Recapture Shale Member

A possible braided stream and (or) low sinuosity meandering stream with associated floodplains is suggested for the origin for Recapture claystone and sandstone units. This interpretation is based upon the generally continuous but subequal

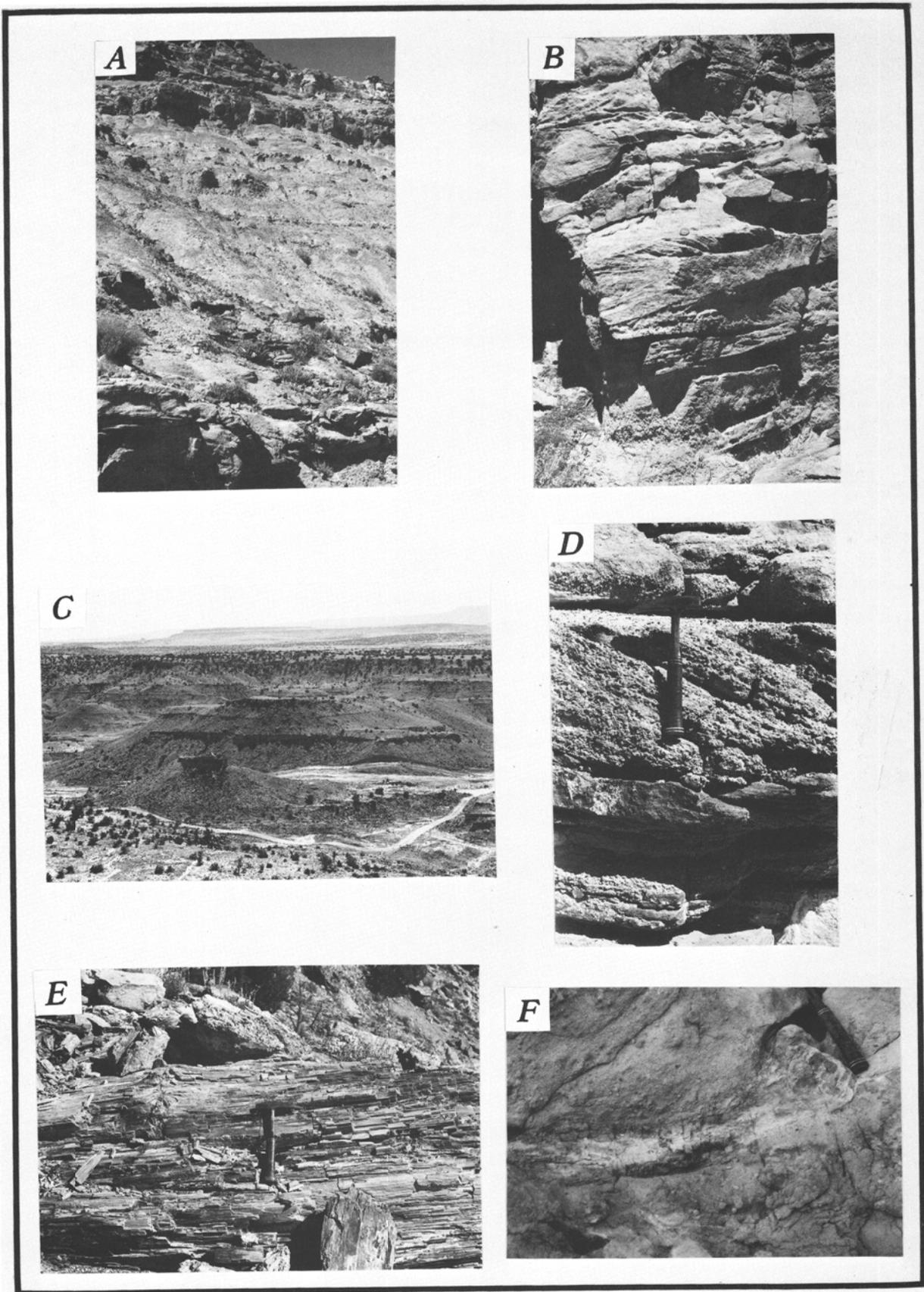


Figure 5.

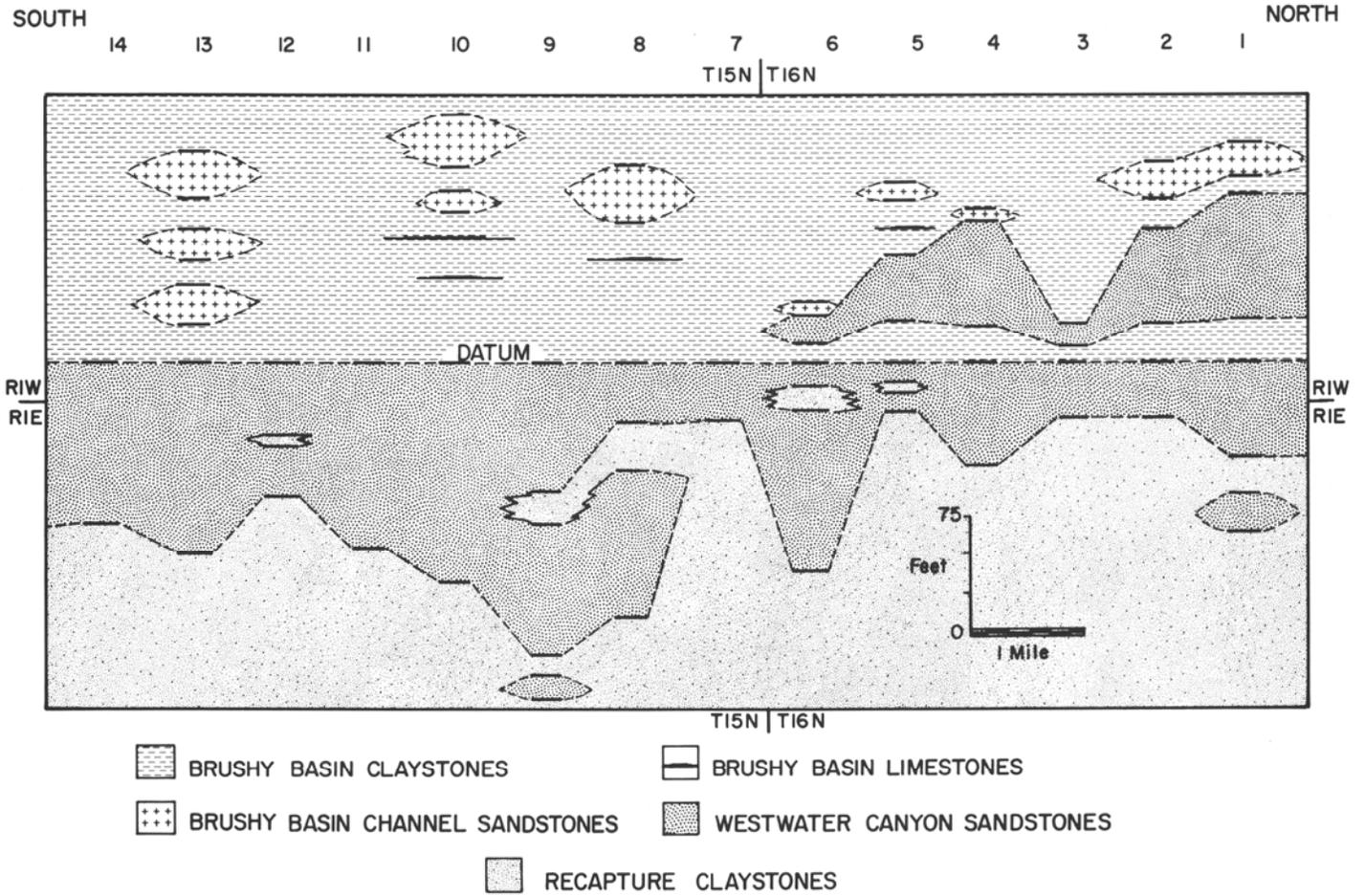


Figure 6. Restored stratigraphic section along Westwater Canyon and Brushy Basin outcrop trend, Ojito Spring Quadrangle, Sandoval County, New Mexico.

thickness of sedimentary units and the intertonguing relationship of sandstone and claystone units. Trough cross-stratification with minor associated planar(?) cross-strata suggest current flow transitional between the lower and upper flow regimes. Local, discontinuous sandstone lenses are believed to represent small accessory stream channels. No dune (large planar cross-strata) deposits were observed. Comparison of the field data with Table 6 of Picard and High (1972) on recognizing lacustrine environments indicates a close resemblance to their fluvial column, suggesting that the lower Morrison lake deposits of Tanner (1968; and this Guidebook) do not extend into the study area. Ruetschilling (1973) recognized a persistent 20 cm thick, micrite bed over a distance of 4 km and interpreted it to be a lake deposit. That bed is not present in the study area.

Regional stratigraphic work by Craig and others (1955, fig. 22) indicates a conglomeratic sandstone and sandstone facies north of Gallup, "supporting the concept of an alluvial plain or fan with an apex near Gallup". Recapture in the study area

belongs to Craig's claystone and sandstone facies, which is located basinward of the main fan in an area of decreasing current flow and subsequent deposition of fine, moderately well sorted sandstones within channels associated with increasingly prevalent floodplain claystone deposits.

Westwater Canyon Sandstone Member

The Westwater Canyon Sandstone is interpreted to have been deposited within an eastward flowing braided stream complex exhibiting some variability through time (fig. 35B of Allen, 1965). The basal, discontinuous sandstone lenses exist in stacked channel sequences, and represent meandering streams. The main continuous, lower unit is extensive throughout the area and represents a well developed braided-stream complex with minor interbedded and intertongued overbank deposits. The upper sandstone unit extends halfway across the outcrop trend in the northern part of the area and

Figure 5. Brushy Basin Member: A, Brushy Basin exposed at Cucho Mesa; thin beds are micrites, with local channel sandstone and more peristant sandstone unit capping the mesa; B, Closeup of capping sandstone unit in the Brushy Basin at Cucho Mesa; trough cross-bedding is well developed; C, Brushy Basin non-resistant claystone and resistant thin local channel sandstone unit; south view; D, Close-up of cross-bedding exhibited in channel sandstone unit; E, Large petrified log present in uppermost channel sandstone of the Brushy Basin; F, Silicified dinosaur bone in coarse channel sandstone unit of the Brushy Basin at Tierra Amarilla Anticline, to the east of the study area.

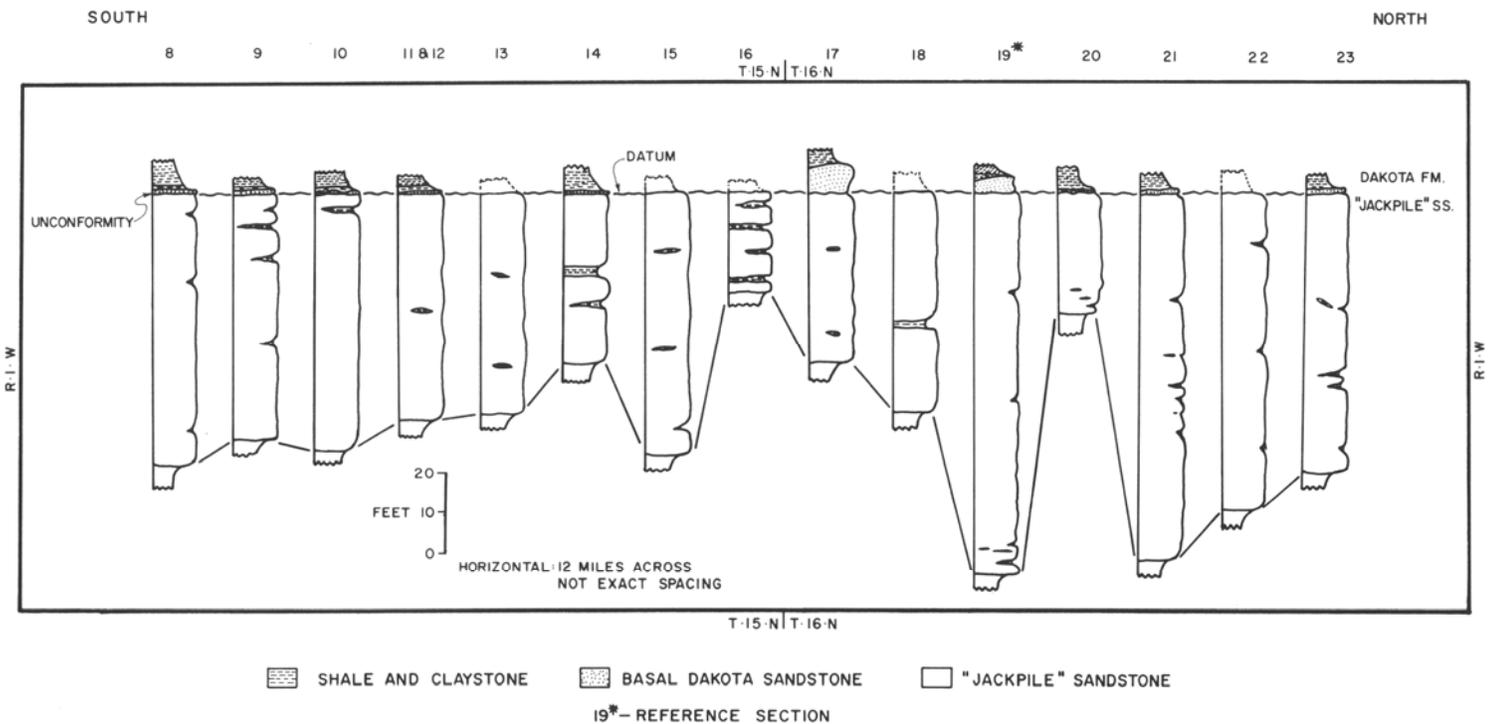


Figure 7. "Jackpile" Sandstone stratigraphic section, Ojito Spring Quadrangle, Sandoval County, New Mexico.

may represent the margin of a braided stream system. The excessive thickness of the total interval infers a gradually widening and slowly subsiding floodplain. The predominance of trough cross-bedding suggests current flow in the upper part of the lower-flow regime. The occurrence of point bars is shown by accessory structures such as planar cross-stratification and occasional parallel strata which may be burrowed.

Regional stratigraphic work by Craig and others (1955, fig. 28) indicates Westwater Canyon facies trends similar to those of the Recapture, but with more areal extent. A conglomeratic sandstone and surrounding sandstone facies occupies a wide lobate area centered north of Gallup, New Mexico. Craig and others (1955) interpreted a broad fan-shaped alluvial plain or "fan" formed by "an alluviating distributary system of braided channels" as the depositional environment. Deposition of the

Westwater Canyon is considered to be a continuation of Recapture deposition with coarser material being available, which Craig thought "reflects a rejuvenation of the source area, in west-central New Mexico."

A possible ancient analogue to the Westwater Canyon may be the Van Horn Sandstone of Precambrian (?) age which has been interpreted as a large alluvial fan system by McGowen and Groat (1971, figs. 3 and 32). The Westwater Canyon in the Ojito Spring Quadrangle may represent the distal, trough-fill cross-strata facies of a large alluvial fan, with the conglomeratic facies of Craig near Gallup representing the mid-fan area. The proximal facies appears either to have been removed by pre-Dakota erosion or has not yet been sufficiently described or discovered in this region.

Brushy Basin Shale Member

Strongly meandering streams with extensive floodplain deposits and temporary fresh-water lakes best explain the local to more persistent, texturally variable, discontinuous sandstone units, abundant claystone units, and thin micrite beds of the Brushy Basin. The medium-scale trough and some planar cross-stratification sets indicate current flow generally in the middle portion of the lower flow regime. Point bar deposits with conglomeratic sandstones, logs, wood fragments, and an occasional dinosaur bone occur along the inside of the stream bends.

This interpretation is in close accordance with Craig and others (1955, p. 157), who stated that "as the west-central New Mexico source area was reduced and ceased furnishing coarse material, Brushy Basin sediments were spread southward ...". Keller (1962, p. 59) indicated that "the amount of ash that fell during deposition of the Brushy Basin often exceeded and masked fluvial effects. At times, and in those places where fluvial actions exceeded volcanic deposition, better sorted sandstones and siltstones were laid down."

Table 2. Locality Index for Measured Sections

No.	Westwater Canyon and basal Brushy Basin	No.	"Jackpile" sandstone
1	NE 1/4, NE 1/4, sec. 15, T16N, R1W	8	SE 1/4, SW 1/4, sec. 22, T15N, R1W
2	NE 1/4, NW 1/4, sec. 23, T16N, R1W	9	SE 1/4, SE 1/4, sec. 21, T15N, R1W
3	NE 1/4, SE 1/4, sec. 23, T16N, R1W	10	NW 1/4, NW 1/4, sec. 10, T15N, R1W
4	S 1/2, NE 1/4, sec. 26, T16N, R1W	11	NW 1/4, SE 1/4, sec. 16, T15N, R1W
5	SW 1/4, NE 1/4, sec. 35, T16N, R1W	12	SE 1/4, NE 1/4, sec. 16, T15N, R1W
6	SW 1/4, SE 1/4, sec. 35, T16N, R1W	13	SW 1/4, NE 1/4, sec. 16, T15N, R1W
7	NE 1/4, SW 1/4, sec. 2, T15N, R1W	14	SE 1/4, NW 1/4, sec. 15, T15N, R1W
8	NW 1/4, NE 1/4, sec. 1, T15N, R1W	15	SW 1/4, NW 1/4, sec. 9, T15N, R1W
9	SW 1/4, NW 1/4, sec. 6, T15N, R1E	16	SW 1/4, SW 1/4, sec. 34, T15N, R1W
10	SW 1/4, NW 1/4, sec. 7, T15N, R1E	17	NE 1/4, SE 1/4, sec. 33, T16N, R1W
11	SE 1/4, NE 1/4, sec. 11, T15N, R1W	18	SE 1/4, NW 1/4, sec. 34, T16N, R1W
12	NW 1/4, NE 1/4, sec. 13, T15N, R1W	19*	SE 1/4, SE 1/4, sec. 28, T16N, R1W
13	SW 1/4, SE 1/4, sec. 14, T15N, R1W	20	SW 1/4, NW 1/4, sec. 28, T16N, R1W
14	SE 1/4, SW 1/4, sec. 18, T15N, R1E	21	W 1/2, NW 1/4, sec. 27, T16N, R1W
		22	NE 1/4, NE 1/4, sec. 21, T16N, R1W
		23	SW 1/4, NE 1/4, sec. 16, T16N, R1W

*Reference Section (see Figure 2E)

"Jackpile Sandstone"

The "Jackpile Sandstone" is interpreted to have been deposited within a roughly eastward flowing braided stream complex, based upon its dominate sandstone lithology, laterally continuous but varying thickness, and abundant large and medium scale trough and wedge cross-stratification sets. The prevalent trough cross-stratification and minor planar and horizontal strata indicates current flow transitional between the lower and upper flow regime. Overbank and floodplain deposits generally are minor components (with some exceptions); conglomerate lenses and planar cross-bed sets may represent point bar deposits. "Jackpile" sandstone unit deposition differs from the Westwater Canyon in being thinner and less extensive. Pre-Dakota erosion along the unconformity may have been extensive, however.

Schlee and Moench (1961) and Moench and Schlee (1967) have previously interpreted the depositional environment for the "Jackpile" in the Laguna area. They stated that "The Jackpile sandstone may be a product of a second major rejuvenation of the area south of Gallup and its composition and internal structure are like those of the Westwater Canyon Member, and its cross-stratification indicates that the sediments were derived from the same direction". They postulated deposition "in an area where broad alluvial plains and belt deposits formed and coalesced, and where distributary and tributary branching of belt sands occurred" (fig. 10 of Schlee and Moench, 1961).

A braided-meandering stream environment may be applicable to "Jackpile" deposits in some areas as the stream gradient decreases and channel characteristics change (fig. 4 of Shelton and Noble, 1974). This would be very difficult to establish, but would be useful to identify as an aid in the exploration of uranium bearing sandstones.

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