Tertiary and Quaternary

Baca Formation

The Datil Formation (Winchester, 1920), a name now abandoned (Elston, 1976, p. 134), has been separated into the Baca Formation, Spears Formation, Hells Mesa Tuff, A-L Peak Tuff and La Jara Peak Basaltic Andesite. Wilpolt and others (1946) designated the basal 684 ft (208.5 m) of Winchester's (1920) measured section of the Datil Formation as the type section for the Baca Formation. This section was measured in the upper portion of Baca Canyon, secs. 4, 5, 8, and 9, T. 1 N., R. 4 W., and is the only published measured section of the Baca Formation at the type locality. Of that section, 365 ft (111.3 m) was "covered" or "not exposed".

At Carthage, Gardner (1910) recovered a tooth of *Palaeosyops*, a small rhinoceras-type animal of Bridger (Middle Eocene) age from the Baca Formation. North of Datil, teeth and bone fragments of *Protoreodon pumilus*, a late Eocene relative of the modern-day sheep, were found in Baca strata (Snyder, 1970). Fossil wood from the Baca has been identified as *Palmoxylon sp.* and *Leguminoxylon sp.* which supports the Eocene age assignment (Snyder, 1971). *Tilia*-type pollen, Jugladaceous forms, and others also indicate the Baca to be at least as young as Eocene (Chaiffetz, in preparation).

Potter (1970), in an unpublished thesis, reported making several partial measurements which he compiled, in his own words, by "somewhat questionable correlations" into a complete section. Potter (1970) found the Baca to be 697 ft (212.5 m) thick at Baca Canyon, secs. 4, 5 and 8, T. 1 N., R. 4 W. The thickness of the Baca is 2500 ft (762.0 m) as indicated by drilling, but in outcrop it does not exceed 1150 ft (350.5 m); typically the thickness is about 600 ft (182.9 m) (Snyder, 1971).

Wilpolt and others (1946) correlated rocks of the Carthage and Joyita Hills areas with those in Baca Canyon. Other formations that are of similar lithologies and close to time equivalent to the Baca include the Eagar, McRae, Cub Mountain, and Galisteo. The age of the Eagar Formation, a westward continuation of the Baca in Arizona (Snyder, 1971), is uncertain but it contains a Cretaceous fauna and coal in the basal portion (Sirrine, 1956). The McRae Formation, Elephant Butte dam area, contains Triceratops and is therefore Cretaceous in part (Lee and Knowlton, 1917). The Cub Mountain Formation, Capitan-Ruidoso area, is post-Laramide to pre-Oligocene in age (Kelley, 1971). The Galisteo Formation, south of Santa Fe, is of uncertain age within a range from Paleocene to Eocene based on limited plant remains (Lee and Knowlton, 1917). Sedimentation in the San Juan and Raton basins continued throughout the late Cretaceous and early Tertiary. Faunal evidence indicates a Eocene age for the San Jose Formation (Lucas, 1977).

Because early Tertiary rocks are similar lithologically, separated geographically, and differing ages, it is reasonable to conclude that sedimentation in New Mexico and western Arizona occurred from the Cretaceous through the Eocene in isolated but somewhat genetically related basins (Tonking, 1957). The times and rates of subsidence and sediment accumulation undoubtedly fluctuated from basin to basin. The stratigraphic position and duration of gaps in the sediment record are difficult to establish because of sparse paleontological control.

The base of the Baca rests unconformably on the Mesaverde, a relationship that can be demonstrated regionally but is difficult to ascertain at a single location. The boundary between the formations changes character laterally and in places is difficult to delineate. In general, the lower Baca boundary is placed at the first occurrence of red shale or sandstone that contains pink-colored potassium feldspar. Often the shales and sandstones of the uppermost Mesaverde take on a greenish hue and this color change is useful in distinguishing the formations.

The contact of the Baca and overlying Spears Formations is marked by alternating beds of Baca and Spears lithologies and was mapped at the lowest bed containing volcanic detritus. Beds of the Baca are arkosic and rich in granitic rock fragments. Beds of the Spears, on the other hand, contain abundant volcanic material. At a distance the Baca and Spears can generally be differentiated on the basis of color and weathering. The Baca strata are various hues of red, generally forming low plains with isolated light-gray conglomerate or sandstone ledges, whereas the Spears crops out as rounded, light-purple, rough-textured sandstone hills.

Potter (1970) divided the Baca into three informal members. These members are, in ascending order: a lower red mudstone-sandstone member, an arkosic sandstone member, and an upper red mudstone-sandstone member. In the study area three informal members of the Baca are easily distinguished. Potter's (1970) terminology of these members, however, lacks descriptive viability and therefore a slightly modified version of terminology is proposed. The lower red mudstone could more accurately be called the conglomeratic member as conglomerates in the Baca are largely restricted to this portion. The arkosic sandstone member is misleading as arkosic sandstones are found throughout the Baca. A more descriptive name for this subdivision would be the gray sandstone member as this portion differs from the rest of the Baca by its characteristic gray-yellow color. The upper red mudstone-sandstone member of Potter's is sufficiently descriptive. Therefore, the terminology the writer prefers is, from bottom to top: conglomeratic, gray sandstone, and red mudstone members.

An excellent exposure of the Baca Formation 753 ft (229.7 m) thick was measured north of the type locality, W½ sec. 29, T. 2 N., R. 4 W. There a complete section of Baca dips at about 6 degrees south and has the tripartite division discussed above. The conglomeratic member, units 3 through 28, is 319 ft (97.4 m) thick (figs. 24 & 25). The member consists of reddish-brown (10 R 4/4) mudstone with numerous lentils of conglomerate and coarse, arkosic sandstone. The lentils range from 50 to 200 ft (15.2 to 61.0 m) in length and 10 to 30 ft (3.0 to 9.1 m) in thickness. The mudstones are thin to medium bedded and break into small chunks. The sandstone and conglomerate beds are composed of poorly sorted, subangular to rounded, coarse sand and cobbles. The clasts are commonly quartz, pink- and gray-colored potassium feldspar, and lithic fragments. Limestone, several varieties of granites, pegmatitic quartz, several types of quartzites, and occasional gneisses compose the bulk of the lithic fragments found in the lower Baca. The granite pebbles are generally coarse-grained, angular, and often pegmatitic. Three types of granite clasts are present, namely: 1) cream-colored potassium feldspars and quartz, 2) pink-colored potassium feldspars and quartz, and 3) graphic-textured granite. The quartzite clast vary in color and are generally rounded. Granitic

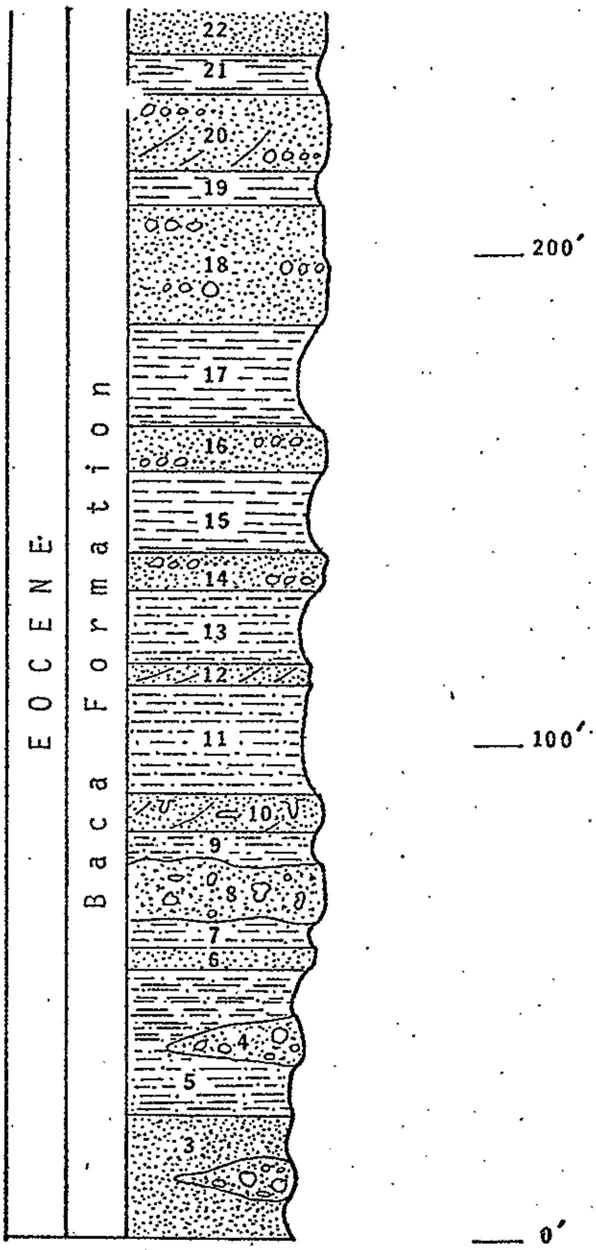

Figure 24. Lower 250 ft (76.2 m) of Baca Formation.

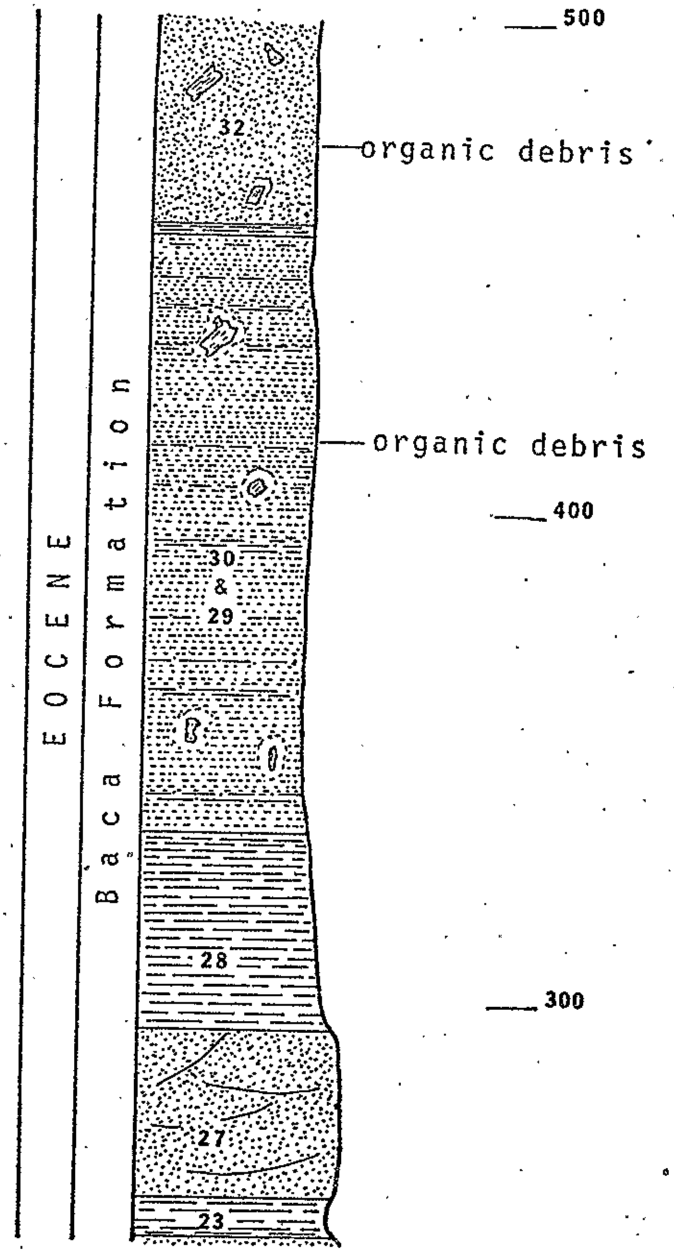

Figure 25. Middle 250 ft (76.2 m) of Baca Formation.

and quartzite fragments are considered to be derived from Precambrian rocks. Rounded limestone fragments are commonly fossiliferous, containing crinoid stems, brachiopods, bryzoans and other fossils of Mississippian to Permian age. Two types of fossilized wood occur in the Baca; one type is unrounded and genetically related to the Baca, and a second type is darker in color, rounded, and presumed to have been reworked from the Triassic (Potter, 1970).

Conglomeratic strata are generally a grayish color in contrast to the reddish hue of the mudstone. The sandstones and conglomerates are more resistant to erosion than the mudstone and form stepped ledges that vary in thickness due to their lenticular nature. Trough and very-low-angle cross-stratification is common in the sandstones. The thickest sandstone or conglomerate unit measured, unit 27, is 35 ft (10.7 m) thick. Siltstones and claystones are burrowed in many places. The burrows are non-branching, vertical and horizontal, about ¼ inch (6 mm) in diameter, and several inches long.

The gray sandstone member, units 29 through 32, is composed almost entirely of interbedded, light-greenish-gray (5 GY 8/1) and thin-bedded yellowish-gray (5 Y 8/1), clayey, sandstones and siltstones (fig. 25 & 26). No red shales occur in this interval. The gray sandstone member is 176 ft (53.6 m) thick, loosely consolidated, and forms slopes or level plains. The rock is composed predominately

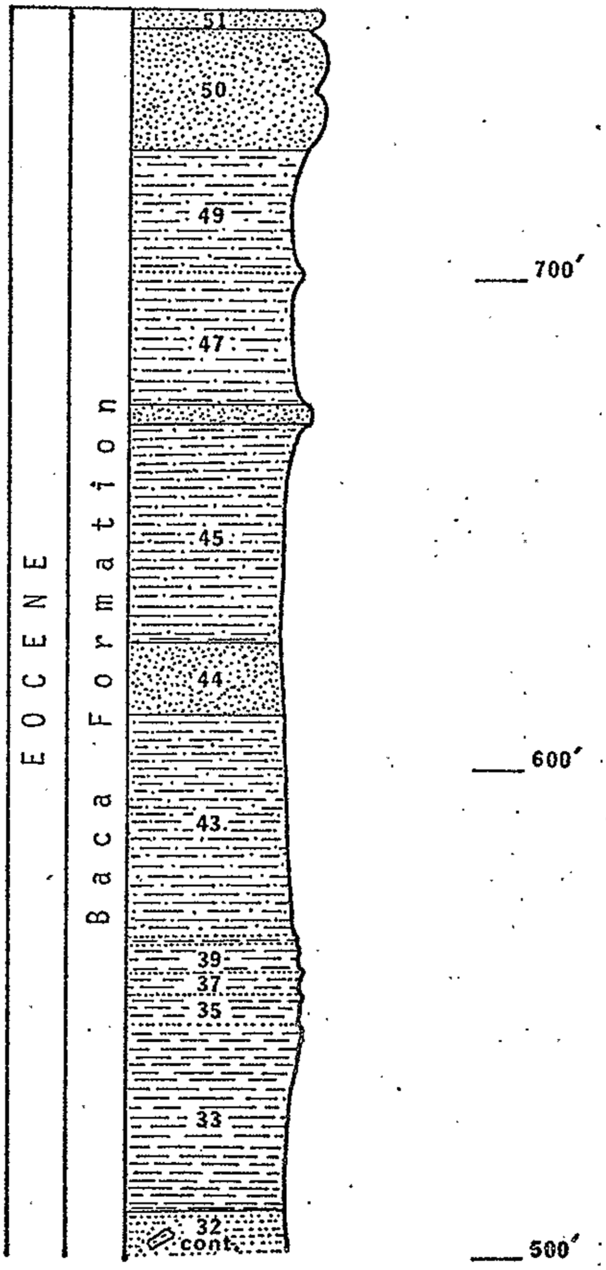

Figure 26. Upper 253 ft (77.3 m) of the Baca Formation

of silt-to coarse-sand-sized quartz and gray-colored potassium feldspar. The grains are moderately sorted and subrounded to subhedral. Yellow limonite halos commonly encircle organic debris and fossilized tree trunks in this member (fig. 27). Conglomeratic cross-bedded sand lenses, as well as limestone beds are present locally, secs 9 and 11, T. 1 N., R. 4 W.

The red mudstone member, units 33 through 51, is 244 ft. (74.5 m) thick and composed mostly of grayish-red (10 R 4/2) to reddish-brown (10 R 4/4) silty mudstone. Thin sandstones, about 3 inches (8 cm) thick, are interbedded in the lower portion of this segment. The sandstones are very light gray (N 8), composed of rounded, well sorted, very-fine-sand-to silt-sized grains. In the upper portion of the member pale-red (10 R 6/2) sandstones as much as 25 ft (8.6 m) thick are interbedded with mudstones. The sandstones consist of moderately sorted, loosely consolidated coarse arkosic sand. Numerous veins of satin spar gypsum and one thin vein of light blue celestite was observed in the upper portion of the Baca at the type locality.

The sand-and silt-sized constituents of the Baca are about 30 percent quartz, 20 percent microcline, 20 percent quartzite, 10 percent chert, and the remaining 20 percent divided among plagioclase, potassium feldspar, carbonate, muscovite, and mudstone grains. The cement of

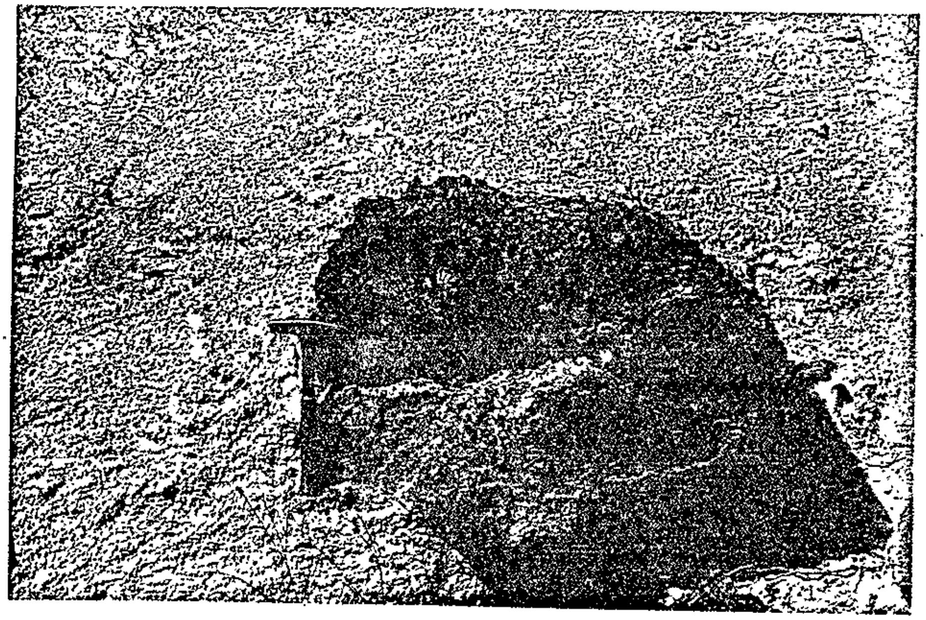

Figure 27. Fossilized tree trunk in gray sandstone segment of the middle Baca Formation. Yellow limonite halo encircles tree trunk. Location is NE¼ NE¼ sec. 16, T. 1 N., R. 4 W.

the sandstones is partly an early generation of silicia but is largely a later generation carbonate. The grains are commonly coated by a thin layer of hematite. Fine-grained hematite and carbonate occurs in shales of the Baca Formation.

The Baca accumulated in one of many basins produced by the Laramide orogeny. The dimensions and shape of the Baca basin are unknown but judging from the present outcrop belt the basin probably was elongate east to west and slightly sinuous between highland masses. Highlands bordering the basin during Baca depositon include: Zuni, Defiance and Lucero uplifts on the north, Joyita Hills uplift on the east, Magdalena uplift to the south, and Mogollon highlands to the southwest. Undoubtedly, smaller, local uplifts also influenced Baca sedimentation.

Snyder (1971) interpreted the climate during Baca deposition to be arid to semiarid, and gave the following as evidence: 1) coarse-grained sediments in deeply entrenched channels; 2) reddish color of the finer grained rocks; 3) lack of abundant organic trash (believed by Snyder to be due to the paucity of vegetation); and 4) presence of continental limestones thought to be caliche. Johnson (1978) advocates a wetter climate, in the range of semiarid to subhumid. As evidence he cites the following: 1) lack of obvious indicators or aridity, such as primary evaporites, wind reworked sand, and carbonates; 2) the fact that caliche, described by Potter (1970), develops best in semiarid rather than arid climates; 3) abundance of root mottling even if actual organic debris is scarce; and 4) humid tropical floras and faunas of neighboring Eocene basins.

Although the writer concurs with Johnson's conclusion that the climate was wet and hot during Baca deposition, certain points should be made. First, limestones found in the Baca north of the Bear Mountains are associated with gray shales and have yielded lacustrine algae (Chaiffetz, in preparation). A lacustrine origin, not soil-profile caliche, is postulated for these beds. Mudcracks in the Baca (Tonking, 1957), suggests alternate wetting and drying.

Second, the MacRae basin that Johnson (1978) advances as proof of a wet climate for the middle Eocene is in part late Cretaceous in age, older than the Baca. The San Jose Formation of the San Juan Basin is unquestionably (Bridger) middle Eocene as in the Baca in New Mexico from the limited faunal evidence available. The fauna of the San Jose Formation are typical of savanna-like upland assemblages (Lucas, 1977).

Thirdly, only the clay constituents of the Baca sediments are characteristically red. Silt and sand clasts are shades of gray with only a few grains with coatings of iron oxides. Magnetite and other iron-bearing minerals in the Baca are mainly unaltered, indicating that the red pigment is not a product of in situ alteration of iron-bearing detrital grains, a process described by Walker (1967). Because the red pigment is almost exclusively in the clay fraction of the rocks the origin of the red color is probably due to the weathering of a soil rich in brown ferric material. The sediment is transported in the brown hydrated form, and converted to a bright red by dehydration and oxidation after deposition (Van Houten, 1968). The oxidation probably was close to the depositional interface because after deeper burial clayey-sediments could not oxidize easily. A seasonally rainy, hot, savanna-like climate is an ideal setting for drying ferric hydroxide to hematite (Schmalz, 1968).

Baca clasts are varied and Snyder (1971) concluded that the Baca sediments were derived from multiple source areas. The clasts in the area studied were derived primarily from granitic, metamorphic and limestone sources. The distance from the source rock must have been short for the following reasons: 1) large size of granitic boulders in the Baca; 2) angularity of some of the constituents; 3) occurrence of euhedral and unaltered feldspars, and 4) presence of limestone clasts. Potter (1970) concluded that "some of the constituents of the Baca were transported no more than a few miles." Blatt and others (1972) state that feldspar grains are fairly durable and can be transported great distances without significant reduction in total volume percentage, but are greatly reduced in size when transported distances of only 20 to 25

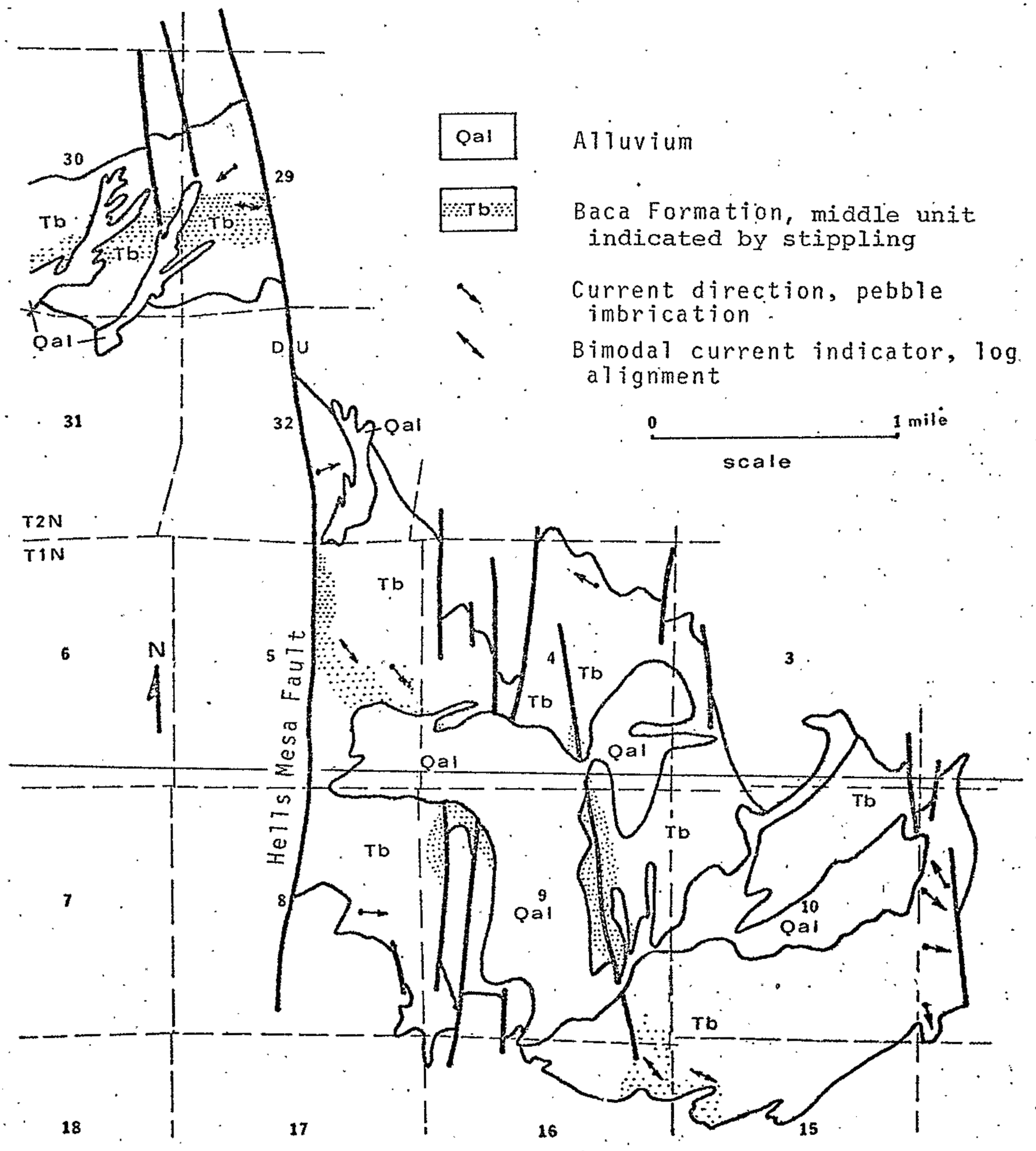

Figure 28. Map showing Baca outcrop belt, northeast of Bear Mountains, with current directions indicated.

mi (32.2 to 40.2 km). Judging from the granite boulders in the lower Baca, a nearby source for at least this material is indicated. Other constituents of boulder size, principally limestone and quartzite, are more rounded and could have come from more distant sources.

Pebble imbrications, cross-bedding, ripples, and long axis of tree trunks in the conglomeratic and gray sandstone members of the Baca indicate a southeastward flowing current (fig. 28). Therefore, the source area probably was to the northwest. Potter (1970) and Johnson (1978) proposed the Lucero uplift and Snyder (1971), the Zuni uplift as the source of the Baca sediments in the area studied. Although the Lucero uplift is closer and could have provided Paleozoic limestone to the Baca, no granites or quartzites were exposed in that area during the Eocene or at present. The Ladron Mountains, with a Precambrian granitic and quartzite core, is a Miocene uplift (Bruning, 1973) and could not have contributed to Eocene Baca sedimentation. The Zuni is the closest known uplift to the northwest that could have been the source of granitic and quartzitic material, but as the Zuni uplift is 60 mi (96.6 km) northwest of the area studied, it seems unlikely that boulders of granite and large angular feldspars could have came from such a distant source. Yet, no alternate source area to the northwest can be suggested.

Until 1978, most workers have considered the Baca as a fluvial channel and floodplain sequence (Potter, 1970; and Snyder, 1971). However, Johnson (1978) interpreted the Baca, from west to east, to be generally a progression of facies from humid alluvial fan, fluvial-meander belt, to lacustrine delta. In the area studied Johnson (1978) calls the lower conglomeratic member, a lacustrine fan delta; the middle gray sandstone member, a distal humid alluvial fan; and the upper red mudstone-sandstone member, a lacustrine fine-grained fan delta.

The writer believes the Baca to be largely a fluvial sequence. The disagreement with Johnson is based on the following reasons. First, evidence for a large lake in this area is lacking. There are no shoreline deposits or supportive faunal evidence. Second, the red color of the sediments is more suggestive of subaerial than subaqueous exposure. Johnson (1978) defends this point by suggesting a shallow, polymictic (frequent overturn) lake or lakes; the frequent overturn would allow oxidation and cause the red coloration. However, because the thicknesses of deltaic sand bodies described by Johnson are as much as 30 ft (9.1 m) thick they therefore require similar water depths. Thirdly, the fan delta complex is composed of many small deltaic sand bodies that would require an extensive fluvial system to supply the material. However, the fluvial facies tract is only a small segment of Johnson's (1978) interpretation. For example, on the west side of the Bear Mountains Johnson (1978) shows the entire Baca section, about 500 ft (152.3 m) of lacustrine deltaic facies, without associated facies. Fourthly, according to Johnson (1978) evidence for a deltaic origin for parts of the Baca are the upward coarsening of grain size per sedimentary package; extensive burrowing; convolute bedding; high mud to sand ratio; and vertical sequence of sedimentary structures. In opposition, the writer points out that convolute bedding, burrowing and root mottling are common in fluvial sequences (Reineck and Singh, 1975). In the Baca the sand:mud ratio is estimated to be about 1:1. This ratio is not outside the realm of fluvial systems. Also, the coarsening upward depositional package that Johnson (1978) promotes may not represent a true depositional cycle. Additionally Bluck (1971) has shown that the head portion of point bars in a coarse-grained meanderbelt can coarsen upward. Also, the writer has found the sandstone bodies in the Baca to be variable in both grain size and sedimentary structures throughout and a typical vertical sequence difficult to document.

Based on the data above the writer concludes that the Baca in the area studied was deposited by streams carrying coarse-grained sediment. The floodplain was savanna-like and the climate subhumid. In the studied area the south-east flowing streams carried granite, quartzite and Paleozoic limestone debris from the Zuni Uplift.