PALEOZOIC BIOSTRATIGRAPHY AND PALEONTOLOGY ALONG THE MOGOLLON RIM, ARIZONA

This one-day field trip permits examination of Devonian, Pennsylvanian, and Permian stratigraphy and biostratigraphy. Pennsylvanian and Permian fossil localities will also be visited.

The field trip guide consists of three separate articles. These involve, in order, paleontology, stratigraphy, and a road log. The road log from Payson to Pine, on pages 34-36 of the New Mexico Geological Society Thirteenth Field Conference Guidebook (1962), might also prove useful.

PALEONTOLOGY OF THE NACO FORMATION IN THE KOHL RANCH AREA, ARIZONA

by

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This trip will traverse part of the Basin and Range Province northeast of Tempe and end up in the transition zone between the Basin and Range and Colorado Plateau provinces below the Mogollon Rim. The total distance is about 230 miles.

We will examine outcrops of Devonian through Permian age, and collect Devonian, Pennsylvanian and Permian fossils. The major collecting site will be in the Naco Formation near Kohl Ranch, discussed below. Possible localities are indicated in figure 1.

GENERAL STRATIGRAPHY

The Naco formation of central Arizona is a predominantly marine sequence of interbedded limestones and terrigenous sedimentary rocks of Pennsylvanian age. The formation is separated from the underlying Mississippian Redwall Limestone by a conspicuous regional disconformity produced by deposition of Pennsylvanian sediments on an ancient Late Mississippian-Early Pennsylvanian karst topography (Huddle and Dobrovolny, 1945, 1952; Brew, 1970; McKee and Gutschick, 1969). The Naco Formation is 1,200 feet thick in east-central Arizona, where it ranges in age from Middle through Late Pennsylvanian (?Atokan through Virgilian). The Naco thins northwestward, however, and wedges out, grading laterally and upward into the Pennsylvanian-Permian Supai Formation (Jackson, 1951, 1952; Brew, 1970; see fig. 1).

Brew (1970) recognized three members in the Naco Formation of central Arizona that were informally designated the alpha, beta, and gamma members. The lowermost, or alpha member, typically consists of a basal, unbedded reddish-brown cherty mudstone, siltstone, or conglomerate overlain by stratified mudstone, siltstone, and sandstone that locally contain fossiliferous limestone lenses. The lower unbedded portion is generally interpreted to represent a regolith formed in situ via solution of the Redwall Limestone, whereas the upper portion consists predominantly of insoluble residues reworked by marine or perhaps both nonmarine and marine agencies (Huddle and Dobrovolny, 1945, 1952; Brew, 1970; McKee and Gutschick, 1969). The alpha member is gradationally overlain by the beta member, a richly fossiliferous sequence of ledge-forming limestones interbedded with less resistant calcareous shales and mudstones. The beta, in turn, grades into the overlying gamma member, a succession of reddish-brown clastics and interbedded limestones produced by the interfingering of marine units and continent marginal and terrestrial redbeds of the southeastward-building Supai delta (Brew, 1970).

The contact of the Naco Formation with the overlying Supai Formation is gradational and time-transgressive. Although the absence of fossils in the basal Supai beds precludes precise age determination, in central Arizona the contact has been tentatively assigned a late Middle Pennsylvanian age (late Desmoinesian). In east-central Arizona, Winters (1963, p. 15) and Brew (1970, p. 134) considered the Naco-Supai contact to be coincident with the Pennsylvanian-Permian boundary.
Figure 1. Selected Paleozoic stratigraphic and fossil localities below the Mogollon Rim, central Arizona.
Pennsylvanian invertebrate faunas are rich and varied in the Naco Formation. The Kohl Ranch locality has been a favorite collecting site for paleontology classes and amateur collectors for many years, and is probably one of the most prolific fossil localities in the state. As such, it has been rather thoroughly depleted of the larger and rarer elements of the fauna, but continues to yield more common species in abundance.

The Kohl Ranch locality occurs in a light brownish-gray calcareous siltstone and mudstone of the beta member of the Naco. Although the locality is not from a measured stratigraphic section, the fossiliferous horizon appears to fall within the stratigraphic interval from bed 18 through bed 23 of the Kohl Ranch section of Brew (1965, unpublished Ph.D. Dissertation, Cornell University, p. 139-140), which is located approximately 1.2 miles to the east. The Kohl Ranch section is shown graphically in figure 2 and the probable stratigraphic position of the faunule is indicated on the section.

The common elements from this locality were described by Brew and Beus (1976) and Webster and Lane (1970). The more abundant species are illustrated in figures 3 and 4. The following species have been recognized at the Kohl Ranch locality:

- **Coelenterata**
  - *Paraconularia kohli*
- **Gastropoda**
  - *Straparollus (Amphiscapha) subrugosus*
  - *Bellerophon (Bellerophon) crassus*
  - *Platystoma* sp.
  - *Loxonenid Gen. and sp. indet.*
Figure 3. Common fossils from Kohl Ranch (used by permission of the S.E.P.M.)
Explanation of Figure 3
(All specimens × 1 unless otherwise indicated)
Nos. 1–3—Bellerophon (Bellerophon) crassus (Meek and Worthen). 1, 3, apertural view, NAU 563, 560; 2, umbilical view NAU 561 (all ×2).
4—Pseudozygopleurid gastropod, side view, NAU 552.
5—Straporollus (Amphiscapha) subrugosus (Meek and Worthen). Umbilical view, NAU 558 (× 2).
6—Phestia sp., side view, NAU 571 (×2).
7—Wilkingia terminale (Hall). Side view, NAU 582.
8–10—Myalina (Myalina) nacoensis n. sp. 8, dorsal view, NAU 572 (×2); 9, left side view, holotype NAU 578; 10, left side view, paratype, NAU 577.
11—Permophorus subcostatus (Meek and Worthen). Left side view of internal mold, NAU 558.
12, 13—Juresania nebrascensis (Owen). Brachial views, NAU 592, 576.
14–19—Derbyia crassa (Meek and Hayden). 14–16, brachial, posterior and pedicle view, NAU 594; 17–19, brachial view, NAU 597, 595, 596.
20, 23—Paraconularia kohli n. sp. Side view, holotype, ASUX-61; paratype, NAU 579 (×2).
21, 22—Cleiothyridina orbicularis (McChesney). Side view and brachial view, NAU 154.
24, 25—Eirmocrinus jeani n. sp. Holotype, NAU 591, viewed from base (× 1) and anterior (× 2).

Bivalvia
Phestia Sp.
Myalina (Myalina) nacoensis
Permophorus subcostatus?
Wilkingia terminale

Brachiopoda
Derbyia crassa
Echinaria semipunctata
Juresania nebrascensis
Antiquatonia portlockiana
Linoproductus prattenianus
Cleiothyridina orbicularis
Composita subtilita
Anthrocospirifer occiduus

Leptosia sp.
Chonetinella sp.
Bryozoa
Ramose, fenestrate and encrusting forms, 6-8 species

Crinoidea
Sciadiocrinus brewi
Eirmocrinus jeani
Delocrinus sp.
2 sp. indet.

The age of assemblage is Desmoinesian based on the age ranges of the above species and the age of underlying fusulinid-bearing beds.
Figure 4. Additional common fossils from Kohl Ranch (used by permission of the S.E.P.M.)
Explanation of Figure 4

(All specimens × 1 unless otherwise indicated)

Nos. 1–11—*Composita subtilita* (Hall). 1, 2, Brachial and side view, NAU 547; 3, 4, brachial and anterior view, NAU 515; 5, 6, brachial and anterior view, NAU 548; 7, brachial view, NAU 546; 8–11, anterior, brachial, side and pedicle view, NAU 549.

12–21—*Anthracospirifer occiduus* (Sadlick). 12, 20, 21, Side, brachial and anterior view, NAU 569; 13, 14, brachial view, NAU 656, 564; 15, 16, brachial and anterior view, NAU 566, 17, brachial view, NAU 568; 18, 19, brachial and posterior view, NAU 570.

22, 28, 29—*Linoproductus prattenianus* (Norwood and Pratten). 22, 29, brachial and pedicle view, NAU 585; 28, brachial view, NAU 583.


REFERENCES CITED


ABSTRACT

In central Arizona basal Paleozoic arkosic cross-bedded sandstone is unconformably overlain by sandstone and carbonate of Devonian age. The basal sandstone, Tapeats-like in character, is shown from paleomagnetic directions and mixed polarities to be temporally equivalent to the Tapeats Sandstone (Early and Middle Cambrian) of the Grand Canyon of northern Arizona.

Strata of the Beckers Butte Member (late Givetian or early Frasnian) of the Martin Formation, directly overlie the Tapeats and form a thin stratigraphic interval that is present discontinuously across much of central Arizona. The lower unit consists of carbonate-cemented sandstone, and sandy carbonate. The upper unit consists of thin beds of aphanitic dolomite. The Beckers Butte is recognized for a distance of about 180 km, from the area of the Salt River Bridge on the southeast to exposures on the Verde River, about 25 km northwest of Jerome. Paleomagnetic directions of the Beckers Butte and overlying strata of the Martin Formation are identical with the reversed polarity paleomagnetic direction of the Temple Butte Limestone (late Givetian? to Frasnian) of the Grand Canyon. The Beckers Butte is unconformably overlain by the fetid dolomite unit of the Jerome Formation, a relationship seen from exposures along the highway just west and east of the bridge across the East Verde River.

INTRODUCTION

The age and stratigraphic relationships of basal Paleozoic sandstone and carbonate strata in central Arizona has long been a matter of concern and of some speculation. Arkosic cross-bedded sandstone exposed along the Mogollon Rim long ago was considered equivalent to the Tapeats Sandstone (Early and Middle Cambrian, McKee and Resser, 1945) of the Grand Canyon of northern Arizona (Ransome, 1916), and such an assignment has since been made by other workers (Huddle and Dobrovolny, 1945; Titley, 1962; Elston and Bressler, 1977; Hereford, 1977). Teichert (1965), in a regional study of Devonian strata of central Arizona, recognized the Tapeats Sandstone at Jerome, Arizona, but assigned highly similar basal arkosic cross-bedded sandstone southeast of Jerome and the Black Hills to the Devonian, although he found no significant lithologic differences between the Tapeats of Jerome and the Tapeats-like strata of the Mogollon Rim region to the southeast. The purpose of this report is to call attention to stratigraphic evidence for the existence of a profound unconformity at the top of the arkosic sandstone (Tapeats) of central Arizona, and to review evidence that allows recognition of a thin basal Devonian unit (the Beckers Butte Member of the Martin Formation) from its type section near the Salt River Bridge on the southeast, to northwest of Jerome. The stratigraphic evidence is supported by paleomagnetic data.

STRATIGRAPHY

REGIONAL RELATIONS

Regional stratigraphic relations extending from the area of the Salt River Bridge on the southeast to Jerome on the northwest are shown in figure 1. Four sections that serve as keys to understanding the regional relationships are depicted in generalized form. They are sections at or near: 1) Salt River Bridge, 2) Roosevelt Dam, 3) East Verde River Bridge, and 4) Jerome. The sections are shown to call attention to stratigraphic relations between units, and to facies changes within the Beckers Butte Member of the Martin Formation. A datum is drawn at the base of the fetid dolomite unit of the Jerome Member of the Martin Formation. Detailed descriptions of these measured sections are reported in Teichert (1965, sections 3, 36, 32, and 41), who has also described the stratigraphy from a number of intermediate exposures.

TAPEATS SANDSTONE

Teichert (1965, p. 26) recognized the arkosic sandstone at Jerome as Tapeats (Cambrian) from the presence of Corophoides burrows. However, farther to the east, Teichert included Tapeats-like arkosic sandstone in the Beckers Butte (Devonian), although such sandstone does not occur in the type section of the Beckers Butte near the Salt River Bridge (fig. 1). About 2 km south of the Salt River Bridge (fig. 1), Tapeats-like sandstone occupies a
Figure 1. Stratigraphic relations and polarities for basal Cambrian and Devonian strata in central Arizona.
swale eroded into Precambrian strata. If strata typical of the Beckers Butte are present at this locality, they lie in a very narrow covered interval separating arkosic sandstone from the overlying fetid dolomite unit of the Martin. In exposures at Roosevelt Dam and near the East Verde River Bridge, Teichert also included thick sections of basal Paleozoic arkosic sandstone in the Beckers Butte.

Attention is called to the existence of an interval of white sandstone at the top of the Tapeats of Jerome and the Tapeats-like beds of the Mogollon Rim. An original dark red to purple coloration seen in underlying beds apparently has been removed, presumably by pre-Late Devonian weathering. Very locally east of the East Verde River Bridge, a pale purple coloration, similar to the color of overlying sandstone of the Beckers Butte, is irregularly superimposed at the top of the bleached sandstone. The zone of bleaching is regionally thickest on the east and southeast, thinner at the East Verde River, and very thin in the Jerome area on the northwest (fig. 1). The bleaching clearly predates deposition of the Devonian strata in central Arizona, and is interpreted to reflect bleaching as the Tapeats lay exposed at a surface of erosion some tens or hundreds of millions of years before deposition of the Devonian strata. Where strata of the Beckers Butte overlie the arkosic sandstone, material of the bleached zone that locally includes pebbles has been reworked into the basal part of the overlying sandstone.

Lithologic consistency, stratigraphic position, and evidence for a substantial stratigraphic break at the top of the arkosic sandstone, together argue for a general correlation of the basal Paleozoic arkosic sandstone of central Arizona with the Tapeats Sandstone of Jerome and the Grand Canyon. This conclusion is supported by paleomagnetic data (Elston and Bressler, 1977) and by the recent discovery of Corophoides by Hereford (1977) in the Tapeats Sandstone south of the Salt River Bridge.

Beckers Butte Member of Martin Formation

The Beckers Butte Member of the Martin Formation was named by Teichert (1965, p. 16) for exposures along U.S. Highway 60, near Beckers Butte and Flying V Canyon, about 2 km northeast of the Salt River Bridge. At the type section, there is no arkosic sandstone reminiscent of the Tapeats, and the member is a simple two-fold unit consisting of gray to brown carbonate-cemented sandstone overlain by a narrow interval of thin bedded aphanitic dolomite. Thin, dark gray shale interbeds in the aphanitic dolomite unit contain a psilophyta flora, which Canwright (1968) in a re-evaluation considers to be late Givetian or early Frasnian in age, somewhat younger than the age originally reported by Teichert and Schopf (1958).

Proceeding westward from the Salt River Bridge, Teichert recognized both units of the type Beckers Butte at Roosevelt Dam, to which he also appended underlying arkosic sandstone of the Tapeats (fig. 1). At Roosevelt Dam, the sandstone unit of the Beckers Butte rests on an irregular erosion surface developed on the Tapeats, and conglomerate material of the Tapeats is reworked into the basal Beckers Butte sandstone. The carbonate-cemented sandstone is characterized by more parallel bedding than the Tapeats, and is mottled pale purplish, unlike the darker and redder hues of the Tapeats beneath the bleached zone. Unlike gray carbonaceous beds at the type locality near Flying V Canyon, the upper aphanitic dolomite unit is purplish red, reflecting a facies change. Chert nodules are present at the top of the aphanitic dolomite unit, a situation that also prevails in the exposure west of East Verde River Bridge (fig. 1).

The section exposed immediately west of the East Verde River Bridge is virtually identical to the section exposed just south of Roosevelt Dam. However, Teichert inexplicably assigned the upper, aphanitic dolomite unit of the Beckers Butte to the fetid dolomite unit of the Jerome Member (1965, fig. 12). Farther to the west and northwest he also failed to recognize the thin aphanitic dolomite unit as separate from the fetid dolomite unit. Thus, from the East Verde River crossing westward, the boundary between the Beckers Butte and Jerome Members was drawn by Teichert at a contact between sandstone below and dolomite above, unlike the stratigraphic relations he defined and recognized near the Salt River Bridge and at Roosevelt Dam.

Our studies call for a revision of the above stratigraphic inconsistencies. At the East Verde River, a two-fold subdivision of the Beckers Butte similar to that seen at Roosevelt Dam is recognized, and the Tapeats Sandstone is removed from the Beckers Butte. This two-fold subdivision is extended northwest to Jerome, and beyond to exposures along the Verde River northwest of Jerome. At the localities shown in figure 1, a thin but distinctive aphanitic dolomite unit underlies the fetid dolomite unit of the Jerome Member, and overlies carbonate-cemented purple sandstone or sandy red or gray dolomite, which in turn overlies the Tapeats Sandstone. The contact between the lower and upper units of the Beckers Butte is sharp, and could be disconformable, although no evidence exists for a large hiatus in deposition. The contact between the aphanitic dolomite unit and the overlying fetid dolomite unit of the Jerome Member also is sharp, and in the area of the East Verde River Bridge can be demonstrated to be unconformable, reflecting an appreciable but perhaps not large hiatus in deposition.

Exposures near the East Verde River Bridge. The Tapeats Sandstone and the Beckers Butte Member of the Martin Formation are exposed short distances west and east of the bridge that crosses the East Verde River (State Highway 87), about 7 km northwest of Payson, Arizona. A complete section of the Beckers Butte is exposed along the
highway west of the river, and should be examined before exposures along the highway east of the bridge are examined. Dark purple-red cross-bedded and cross-laminated arkosic sandstone typify the Tapeats. The upper part of the Tapeats is marked by a white, bleached interval that is about 1.5–2 m thick. Pale purple mottled, carbonate-cemented sandstone of the lower unit of the Beckers Butte Member of the Martin Formation conformably overlies the Tapeats. The main bedding is characteristically parallel-beded, within which cross-laminations and small scale cross-bedding occur. The upper aphanitic dolomite unit sharply overlies the lower sandstone unit, and is 1 m thick. Flattened nodular chert occurs at the undulating contact with the overlying fetid dolomite unit of the Jerome Member of the Martin Formation (see Teichert, 1965, p. 31, fig. 12). Hematite nodules are present in the aphanitic dolomite unit and in the lower part of the fetid dolomite unit. Hematite nodules also are found in the Beckers Butte Member at Roosevelt Dam and Jerome (fig. 1).

East of the bridge across the East Verde River, the fetid dolomite unit rests on an erosionally truncated section of the Beckers Butte. The aphanitic dolomite unit and beds of the upper part of the lower sandstone unit of the Beckers Butte are missing. Additionally, a prismatic-weathering red paleosol or regolith, a few centimeters thick, locally can be observed to separate the Beckers Butte and Jerome Members (fig. 1). (Indiscriminate sampling of this regolith should be avoided because of the scarcity of material, and the exposure should be preserved so that future generations of geologists can observe this rare fossil soil.) The contact of the base of the Beckers Butte with the underlying Tapeats Sandstone is perfectly exposed in the road-cut. It is here that a very pale purple coloration, similar to the color of the overlying Devonian sandstone, can be seen to be locally superimposed at the top of the white, bleached zone that marks the top of the Tapeats Sandstone.

The abrupt truncation of a significant part of the Beckers Butte in the area of the East Verde River may reflect a small structural adjustment, one that occurred at about the boundary between Middle and Late Devonian time. The presence of this unconformity can serve to explain the absence of the Beckers Butte at places in central Arizona, an absence that could be due either to erosion or to nondeposition. Some of the sections measured by Teichert (1965) show conglomerate and dolomite beds in the interval that can be assigned to the Beckers Butte. Conglomerates interbedded with dolomitic sandstone strata may simply reflect local sources from nearby hills of Precambrian rocks, which persisted in central Arizona throughout much of Paleozoic time. The possibility exists that some strata locally overlying the Tapeats and underlying strata that are more or less typical of the Beckers Butte could be considerably older than Middle Devonian, but such remains to be demonstrated.

**Exposures near Jerome.** Strata overlying the Tapeats Sandstone and underlying the fetid dolomite unit of the Martin Formation consist of red-brown and gray sandy dolomite, overlain by thin beds of red aphanitic dolomite that weather gray. The entire unit has been called the “dolomite facies” of the Chino Valley Formation (Cambrian?) by Hereford (1975), whose Cambrian (?) age assignment has since been changed to Devonian (Hereford, 1977) for reasons mostly summarized in this report, and largely devolving from an informal field conference held February 1976. The two-fold subdivision of the “dolomite facies” at Jerome was not recognized by Hereford, and no detailed stratigraphic correlation of these rocks can be made either with the “conglomerate facies” or with the slightly farther removed “lithic sandstone facies” of the Chino Valley Formation in the Chino Valley area. In contrast the two-fold character of the Beckers Butte is recognizable across central Arizona. Changes in lithology and color can be attributed to more or less gradual changes in facies.

On stratigraphic and paleomagnetic grounds, the interval between the Tapeats Sandstone and the fetid dolomite unit of the Jerome Member of the Martin Formation at and near Jerome is assigned to the Beckers Butte Member of the Martin Formation, a name that has clear priority. Formal revision of the stratigraphic nomenclature in the Chino Valley area is the subject of another paper.

**PALEOMAGNETIC DIRECTIONS AND POLARITIES**

Plots of the mean directions for Cambrian and Devonian strata of northern and central Arizona are shown in figure 2. The directions are thermally cleaned directions that are reported and discussed in Elston and Bressler (1977). The normal polarity directions (declination ~270°) for the Tapeats Sandstone of northern and central Arizona are virtually identical, as indicated by overlap of cones of confidence drawn at the 95 percent confidence level. Both the normal and reversed polarity directions for the central Arizona Tapeats are shifted toward the reversed polarity Devonian direction. The greater scatter of directions seen in the Tapeats of central Arizona (reflected by the larger cones of confidence) results from secondary overprints. One overprint was impressed during the Devonian when the Tapeats lay exposed before deposition of the Beckers Butte. This resulted in a “streaking” of some normal and reversed polarity directions toward the Devonian reversed polarity direction, implying a secondary magnetization shortly before deposition of the Beckers Butte. A second much younger overprint reflects recent exposure and weathering, and results in some directions that are “streaked” between the normal polarity present field direction and the normal and reversed polarity Tapeats directions. In spite of the
overprints, distinct normal and reversed polarity directions are obtained from the Tapeats of central Arizona (fig. 2), and the means of these directions lie close to the normal and reversed polarity directions obtained from the Tapeats of the Grand Canyon.

It can here be noted that the polarity zonation of the Tapeats Sandstone of the Grand Canyon is marked by an interval of reversed polarity in the upper part of the formation, and that overlying strata of the Bright Angel Shale also appear to be entirely of reversed polarity (Elston and Bressler, 1977). The lower two-thirds of the Tapeats of the Grand Canyon is of mixed polarity (Elston and Bressler, 1977, fig. 2). The existence of mixed polarities in the Tapeats of central Arizona (fig. 1) thus indicate that much of the central Arizona Tapeats is temporally equivalent to the middle and lower parts of the Tapeats of the Grand Canyon.

In contrast to the mixed polarity directions seen in the Tapeats Sandstone, a single reversed polarity direction is obtained from Devonian strata of both northern and central Arizona (fig. 2). Following thermal cleaning, the paleomagnetic directions are essentially identical. (Although only data from the East Verde River Bridge section are shown in figure 2, similar directions have been obtained from other sections of the Beckers Butte.) The Devonian direction lies far from either the normal or reversed polarity Cambrian Tapeats direction, which has allowed a Devonian “"streaking"" of the Tapeats directions to be clearly identified on plots that show the directions of individual samples. The very tight grouping of directions seen from samples of Devonian strata of both northern and central Arizona reflects the lack of porosity of the rocks and the lack of percolation of ancient and recent ground waters, and thus a general lack of secondary magnetizations.

The paleomagnetic data, in summary, show distinctive directions and polarities between rocks of Cambrian and Devonian age in both central and northern Arizona. The change in paleomagnetic direction in central Arizona corresponds to the stratigraphic position of the unconformity at the top of the Tapeats Sandstone. Very locally, remagnetization of the uppermost Tapeats below its contact with the Beckers Butte has occurred. Such remagnetization is documented in the uppermost Tapeats exposed east of the East Verde River Bridge, where a Devonian paleomagnetic direction has been obtained from the uppermost part of the “bleached” Tapeats that now exhibits a pale purple color, presumably imposed at the time of deposition of the Beckers Butte.

**SUMMARY**

Stratigraphic relations and paleomagnetic data indicate that the basal Paleozoic Tapeats-like sandstone of central Arizona is temporally equivalent to the Tapeats Sandstone (Early and Middle Cambrian) of the Grand Canyon.
Basal-most Devonian strata that directly overlie the Tapeats in central Arizona are those of the Beckers Butte Member of the Martin Formation. The upper unit of the Beckers Butte consists of thin beds of aphanitic dolomite, which at the type section near the Salt River Bridge contain flora of late Middle or early Late Devonian age. Sandstone, carbonate, and locally conglomerate of the lower unit, and the upper thin aphanitic dolomite unit of the Beckers Butte are separated from overlying beds of Martin Formation by an unconformity marking a brief but appreciable hiatus in deposition. The Beckers Butte is discontinuously preserved across central Arizona, from the area of the Salt River Bridge on the southeast, to exposures along the Verde River northwest of Jerome, a distance of more than 180 km. Paleomagnetic directions from the Beckers Butte and from overlying strata of the Martin Formation are entirely of reversed polarity, and are identical to paleomagnetic directions obtained from the Temple Butte Limestone (Late Middle ? and early Late Devonian; Walcott, 1883; Noble, 1914; D. Schumacher, 1975, written communication) of the Grand Canyon of northern Arizona. Paleontologic and paleomagnetic data thus suggest that deposition of Devonian strata in northern and central Arizona began at about the same time.

REFERENCES CITED
faulting with the north block being displaced downward. Such a hypothetical fault probably lies beneath the alluvial fill of the Salt River; this fill is only about 12 feet deep in the vicinity of Tempe Butte.

Aqueduct across the main channel of the Salt River. Exposed on the surface of the river bed is a lag gravel which lies on top of the sandy gravel alluvium of the Salt River. The road across this part of the floodplain is often flooded during periods of intensive or extended precipitation.

STOP 2. At 10 o'clock we can see the unique morphology of the Papago Buttes. Camelback forms a suitable background. The Papago Buttes are not buttes either in a geologic sense but represent highly dissected remnants of a complexly faulted structure which probably formed after Middle Miocene time. The Procamelus-bearing sediments of Tempe Buttes were apparently caught up in the same faulting episode which isolated the Papago Buttes blocks. The arkosic conglomerates and breccias comprising the main rock type of the "buttes" were apparently derived by rather rapid erosion of the Precambrian granitic and metamorphic rocks which are now exposed in the subdued hills and slopes along the eastern flanks of the "buttes" and often between them. Fragments of the weathered and eroded source rock were transported by streams and mudflows and were quickly deposited on rather steep slopes then existing. The arkosic sediments dip toward the west. Other "buttes" of the area are made up of dactitic ashflow tuffs of probable middle Tertiary (Miocene?) age; these rocks form bold outcrops much like the coarse arkosic sediments. The undulating surface of a pediment cut into bedrock radiates outward in all directions from the Papago Buttes.

Cut into the arkosic and tuffaceous sediments are rock shelters called "taffoni." These small, spherical to ellipsoidal pockets and cavelets form by cavernous weathering a little-understood process which probably is the result of hydration of feldspars and biotite to form clays and salts. The rock shelters reach exceptional sizes in which ceiling heights are 50 feet, depths are 25 feet and lengths are 150 feet; however, average measurements are much smaller. Small shelters tend to be spheroidal and aligned along joint and bedding planes. Once these pockets reach a diameter of about 8 feet, they begin to grow transverse to joints and bedding.

Wind is known to be a factor in cavernous weathering (Jennings, 1968), but contrary to popular belief, windblown particles do not cut the taffoni (Pewé, 1974). Apparently the primary roles of wind are (1) to remove thin spalls broken from bedrock by cavernous weathering, and (2) to direct precipitation moisture into the rock shelters. In this part of the Phoenix Basin the dominant wind direction is from the east; on the Papago Buttes taffoni are most common on east- and south-facing slopes. However, pockets and niches are rare on steep slopes no matter what their orientation.

Road goes up scarp of the second highest terrace of the Salt River terrace system. Intersection of Scottsdale Road and East McDowell Road. Turn right and proceed east.

Alma School Road.

Turn left onto Arizona Highway 87.

A gravel pit complex from which streamwashed, sandy gravels of the Salt River are being extracted for commercial purposes can be seen on the right.

Remnants of an ancient Hohokam irrigation system can be seen near the dissected scarp of the second highest terrace of the Salt River, the Mesa Terrace (Pewé, 1978). These people dug and maintained this network from the 10th through 13th centuries A.D. A total of about 125 miles of canals were built in the Salt River Valley. Each canal had to lie at just the right slope to provide water movement, but not erosion. The extensive system developed by these early peoples is testimony to their ingenuity and industry.

Silty-sandy slopewash covers the gravels of the second highest terrace. Ahead are Sawik Mountain and Mt. McDowell.

As we drop off the surface of the second highest terrace onto the next lower level we can see to our immediate right that we are driving across sandy deposits of low-angle alluvial fans. These fans are derived from our left by the natural dissection of the two highest terraces of the Salt River, the Sawik and Mesa Terraces. The light brown, sandy
fan deposits contrast sharply in color and grain size with the underlying gravelly aluvium.

1.2 13.6 Beeline Drag Strip on the right. Across the Salt River to the south we can see the graded profile of a pediment against the skyline. This is one of a series of coalescing pediments which grade to the floodplain of the Salt River and to the Phoenix Basin. Periodic uplifts of the Mazatzal Mountains to the east caused pediment dissection and formation of terraces along the Salt River. Evidence for at least four episodes of uplift are the four major terraces along the Salt River; these surfaces converge in a downstream (west) direction (Péwé, 1971, 1978).

1.0 14.6 Crossing of the Arizona Canal. This irrigation system was constructed after Granite Reef Dam was completed in 1908; waters of the Salt River are diverted into this canal 3.6 miles to our east at Granite Reef Dam. An earlier version of the Arizona Canal was begun in 1883. This system drew its water directly from the bed of the river without benefit of a diversion dam.

1.5 16.1 Road climbs up the low-angle surface of an alluvial fan derived by the dissection of Salt River terraces. Ahead is Mt. McDowell. The basal rock of this prominent landmark is Precambrian quartz monzonite. Overlying this granitic material outcrops a rather thick sequence of reddish Tertiary (?) arkosic conglomerates and breccias. A series of thin basalt flows is sandwiched between the arkosic sediments and a thick sequence of mid-Tertiary dacite ash-flow tuffs that comprise most of Mt. McDowell. The entire sedimentary section dips toward the southwest. Mt. McDowell is a horst block surrounded on all sides by faults.

0.9 17.0 First outcrop of the Mt. McDowell arkose along Highway 87.

0.3 17.3 To the right you can see part of the basalt flow unit outcropping on the lower flanks of Mt. McDowell. To the left at 10 o'clock the Precambrian metamorphic-igneous terrain of the McDowell Mountains appears a drab gray compared to the colorful sedimentary sequence of Mt. McDowell proper.

1.2 18.5 First roadside outcrop of the Precambrian quartz monzonite basement rock in the Mt. McDowell area.

0.8 19.3 Junction of Highway 87 with Shea Blvd.

1.6 20.9 Highway 87 now descends to the Verde River floodplain. The road crosses a typical gullied surface of the pediment (Péwé, 1978) cut into Precambrian quartz monzonite and Tertiary valley-fill sediments.

0.5 21.4 Junction of Highway 87 with access road to Fort McDowell Indian Reservation. Ahead across the Verde River you can see a very prominent high-level surface (Pope, 1974). This terrace is made up entirely of Cenozoic valley-fill sediments which have been reworked by the Verde River to form a surface equivalent in elevation and age to the Mesa terrace of the Salt River. The bold vertical cliffs of the Verde River terrace are supported by a 30- to 40-foot thick caliche zone which is very old and partially silicified.

0.4 21.8 Crossing of the Verde River. The waters of this perennial stream are derived from faults at the head of numerous tributaries draining the Mogollon Rim area (Feth and Hem, 1962).

0.7 22.5 To the right we can see part of the highest terrace of the Salt River.

0.4 22.9 The road traverses Tertiary valley-fill deposits. The glacial surface to our right is being cut into these rather soft sediments and is graded to a low terrace of the Salt and Verde Rivers.

0.6 23.5 Note the well-developed, typical caliche beds and zones in the valley-fill sediments. These features suggest that the climate during formation of this sequence was little different from the present arid climate of this area.

0.9 24.4 To the right front is Stewart Mountain, a mass of Precambrian quartz monzonite surrounded by Tertiary valley fill.

1.1 25.5 Ahead Four Peaks stands boldly against the sky. Amethyst is commercially mined from this area.

7.7 33.2 STOP 3. Desert Vista turnoff. To our southeast on the skyline we see a rough, mountainous terrain dominated in the center by Weaver’s Needle. These highlands are famous in Arizona’s history and legends. The Goldfield and Superstition Mountains comprise the right portion of the mountains; the Cauldron Complexes form topographic lows in the center between us and Weaver’s Needle; Geronimo Head lies on the north (left) end of the complex. This middle Tertiary volcanic terrain has been described by Sheridan (this guidebook) and Sheridan,
Stuckless, and Fodor (1970). Structurally the area is made up of at least two highly-faulted cauldrons surrounded by a higher, relatively flat-lying, unfaulted volcanic plateau made up in large part by pyroclastic ash-flow tuffs derived from the cauldrons. Weaver’s Needle is often described as a classic volcanic neck, but is now known to be an erosional remnant of ash-flow tuffs which formerly extended completely around the Superstition cauldron.

The oldest rocks in the Superstition-Goldfield Mountains area are Precambrian granites. These igneous rocks are unconformably overlain by reddish, arkosic conglomerates such as we have seen cropping out on the lower flanks of Mt. McDowell. Overlying the arkosic sediments is the volcanic sequence which you see before you. This volcanic sequence can be divided into three distinct episodes: (1) an early stage of dome and lava flow formation by latites and basalts; (2) a thick sequence of more silicic rhyodacite to rhyolite welded ash-flow tuffs comprising several cooling units and associated with the collapse of the central cauldrons; and (3) a late stage emplacement of rhyolite-rhyodacite domes on the cauldron margins followed by flooding of the cauldron center by thin basalts at the end of the volcanic cycle.

To the north from Geronimo Head the Precambrian granitic and metamorphic rocks of the Mazatzal Mountains form a distinctively different topography than that which we have been discussing.

1.1 34.3 Directly ahead is an excellent example of spheroidally-weathered blocks of coarsely crystalline intrusive granitic rocks. To the left (northwest) we can see a small mesa capped by a lava flow. Sugarloaf Mountain rises just beyond the mesa.

1.2 35.5 STOP 4. At this locality spheroidal weathering is especially well exhibited. Evidence that most of this type of weathering is accomplished beneath the ground surface is seen in roadcuts which we will see later. There unweathered “core stones” surrounded by weathered “gruss” are exhibited. The piles of rounded blocks you see in this area represent residual accumulations of these core stones left when this gruss is stripped by erosion.

0.7 36.2 Here a north-south trending dike stands about 30 feet above the surrounding quartz monzonite. This is a classic example of differential weathering.

1.7 37.9 A large basalt dike in quartz monzonite is seen in the left roadcut.

0.8 38.7 Crossing of Mesquite Creek.

0.2 38.9 Crossing of Rock Creek. Note the Tertiary volcanics outcropping in this area.

1.4 40.3 In this area the Tertiary basin-fill deposits are overlain by later volcanic flows. These flows commonly form planar surfaces capping many of the hills and form conspicuous dipslopes.

5.1 45.4 Note the conspicuous fault in the left road cut. This is a normal fault with a block of Precambrian quartz monzonite uplifted into contact with Tertiary basin-fill deposits.

0.6 46.0 Spheroidal weathering in this area indicates that the bedrock is coarsely jointed, intrusive granitic rocks.

3.3 49.3 Entrance to Sunflower store and cafe. To the northwest Mt. Ord rises to 7,128 feet elevation as the high, rounded mountain with the towers on top. This landmark is composed of early Precambrian pyroxenite that intruded still older schists. The pyroxenite has in turn been intruded by later Precambrian quartz monzonite.

0.1 49.4 Basalt lava flow and volcanic ash are exposed in the left roadcut.

0.4 49.8 Road passes down onto the floodplain of Sycamore Creek. This stream eventually empties into the Verde River to the west.

6.8 56.6 STOP 5. In the roadcuts on either side of the road the Tertiary basin fill is cut by a high-angle normal fault. At first glance this feature appears to be a dike; the zone of disturbance is bounded by discolored zones and varies in width from 25 feet on the south side of the road to 8 feet on the north side. Closer inspection reveals that the tannish-gray “dike” is in reality a highly comminuted gouge zone containing numerous fragments of Precambrian igneous and metamorphic rocks. There is no evidence that the heat associated with intrusion of an igneous dike has affected these small fragments. The material we see is quite soft and dike rock would be quite hard. Evidence of solution activity along and within the fault zone is the discolored border zone, the light color of the
I'gouge, its uniform appearance, and the presence of small veinlets of calcite within the gouge. The presence and shape of the drag fold within the basin-fill sediments indicates this break is not a thrust fault.

0.3 56.9 In the right roadcut a dike cuts across the basin fill.

0.3 57.2 In the left exposure, flow-banded dacite outcrops. Tertiary elastic sediments are seen in the right roadcut.

0.7 57.9 Highly contorted, Precambrian slate-phyllite can be seen to the left along the highway. Greenstone (altered basalt) is intercalated with these rocks.

0.7 58.6 STOP 6. Canyon of Slate Creek. These rocks are typical of the metamorphic sequence which forms the core of the Mazatzal Mountains (Wilson, 1939). They were formed from sediments during the episode of extensive and intensive mountain building termed the "Mazatzal Revolution." Damon and Giletti (1961) used rubidium-strontium dating to show that this orogeny occurred between 1.2 and 1.5 billion years ago. Many geologists correlate the low-grade metamorphic rocks you see here with the higher-grade Vishnu-Brahma Schist Complex found in the Inner Gorge of the Grand Canyon. Both metamorphic units were extensively intruded by granitic masses during the last stages of the Mazatzal Revolution. Slates, phyllites, and schists containing talc and chlorite minerals can be found at this site. On the ridges to the northeast resistant beds of Precambrian quartzite in near vertical attitude stand above the softer surrounding slates and phyllites.

1.9 60.5 In the left bank, Tertiary basin-fill material is in normal fault contact with Precambrian phyllite.

2.9 63.4 Tertiary terrestrial deposits are faulted against a block of altered and sheared quartz monzonite of Precambrian age in the left roadcut.

0.2 63.6 The Tonto Basin can be seen to the right front across the dissected basin fill.

1.6 65.2 The conglomerate-filled channel exposed in the right bank records an ancient cycle of dissection of the older gravels in this area.

0.2 65.4 Directly west from here differential weathering has exposed a very resistant bed of the Precambrian Deadman Quartzite along the lower flank of the Mazatzal Mountains. This unit is one of the last units deposited before the inception of the Mazatzal Revolution and so is one of the youngest rocks incorporated in that deformation.

Directly north of here the very light-colored, Pliocene lake beds of the Payson Basin can be seen. The Payson Basin is one of a series of structural troughs which trend northwest to southeast across Arizona and lie in the Transition Zone between the Colorado Plateau and the Basin and Range Physiographic Provinces. The Verde Basin lies to the northwest and the Tonto Basin lies to the southeast (Royse and Wadell, 1970; Lance, Downey, and Alford, 1962). The Payson Basin is bounded on the southwest by the Mazatzal Mountains and on the northeast by the Sierra Ancha Mountains. Similarly to the Verde Basin, the Payson Basin apparently developed in middle to late Tertiary time and we can speculate that this depression also may be the result of block faulting. Much evidence of faulting is seen in the area, but no bounding faults have been found.

The sedimentation history of the Payson Basin is as complex as that of the Verde Basin. Pedersen (1969) has determined that an early stage of extensive alluvial-colluvial fan development around the basin margins was contemporaneous with deposition of fluvial silts and sands along the basin axis. As the basin was filled by these clastic sediments, small, local lakes developed in topographic lows and silty clays and limestones were deposited in them. Remains of freshwater mollusks have been found in the calcareous deposits (Taylor, 1968).

Deposition of the fluvial and lacustrine deposits was followed by an alluvial stage characterized by development of broad alluvial fans. Later these fan surfaces were altered by stream dissection and the pediment or terrace surfaces you see cut into the relatively soft basin-fill material developed during this erosion.

Part of the carbonate-silt facies of the lacustrine sequence of the Payson Basin is exposed in the roadcuts on either side of the road. The limestone beds here reach one foot or more in thickness and form resistant, vertical outcrops.

0.4 67.5 Junction of Highways 87 and 188.

3.7 71.2 Crossing of Rye Creek. To the left across
the floodplain of Rye Creek one can see part of the fine-grained facies of the early basin-fill stage interbedded with fluvial gravels. Rye Creek flows to the southeast from its source near the East Verde River and its course may be aligned along an ancient drainage system that was later modified by volcanism and perhaps stream piracy to form three aligned stream systems in this area: the Verde River, the East Verde River, and Rye Creek (Pedersen, 1969).

1.6 73.1 The "town" of Rye.

2.9 75.8 In the left roadcut the Tertiary basin-fill deposits are offset by a normal fault which also displaced the altered, older Precambrian diabase.

0.7 76.3 Roadcut through the same diabase unit.

4.6 81.0 We are now driving through the juniper-pinyon woodland of Merriam's Upper Sonoran Life Zone. Until now we have been passing through desert-grasslands and chaparral of this same zone.

0.3 81.3 To the north we can see the Mogollon Rim on the skyline capped by the Coconino Sandstone. This gigantic scarp extends northwest to southeast across central Arizona and marks the southern boundary of the Colorado Plateau Physiographic Province. The Mogollon Rim is separated from us by a lesser scarp termed the Diamond Rim; we will discuss the significance of this feature later. The Mogollon Rim is a retreating scarp being cut by erosion into the upper Paleozoic sedimentary rocks to the north; the rim began its retreat from a fault scarp termed the Diamond Rim fault.

0.8 82.1 First outcrop of the beautifully cross-bedded, Middle Cambrian Tapeats Sandstone along the highway (fig. 1). This sedimentary unit formed during the advance of the Cambrian sea that progressively lapped onto Mazatzal Land, a hypothetical highland in this part of central Arizona that persisted intermittently at least through the Paleozoic (Stoyanow, 1936). This sea entered the area from the west. This Cambrian basal sandstone shows evidence of reworking of the purplish, arkosic debris covering the low-angle weathered surface then existing. The lower Tapeats is purplish in color, fine grained, and arkosic in composition.

0.2 82.3 Entering Payson. This settlement lies at 4,887 feet elevation along the lower limit of ponderosa pine, the characteristic plant of Merriam's Transition Life Zone.

1.6 83.9 Junction of Highways 87 and 160. Turn right and proceed east toward Heber and Snowflake.

1.1 85.0 In the roadcuts here and for several miles to the east, weathered quartz monzonite outcrops. These Precambrian granitic rocks are thought to be part of an extensive igneous-metamorphic complex which includes the Bradshaw Granite of the Bradshaw Mountains to the west and the Ruin Granite in the Superior area to the southeast. To our south and southeast the terrain is underlain by older Precambrian metasediments and altered volcanics which have been described by Gastil (1958). Resistant quartzite units within this sequence support many of the linear ridges and higher mountains of the area.

0.7 85.7 To the northeast we can see Diamond Point, one of the highest points along the Diamond Rim. This landform is the site for a fire lookout tower. The Diamond Rim is a subsequent fault-line scarp that probably began its retreat from the vicinity of the Diamond Rim fault to its present position during Miocene time (Titeley, 1962). Diamond Rim fault is a west-northwest-trending normal fault system which northwest of Payson has brought the Tapeats Sandstone and the Martin Fm and Redwall Limestone down into...
fault contact with Precambrian granitic rocks. These and later Paleozoic units have been stripped almost entirely from the Precambrian basement complex in the area of our present location (Huddle and Dobrovolny, 1952; Kottlowski and Havenor, 1962; Teichert, 1965; and McKee and Gutschick, 1969).

0.9 86.6  Star Valley.
6.4 93.0  To the left and just below Diamond Rim, the purplish, bold outcrops are of Middle Cambrian Tapeats Sandstone. In this area Diamond Rim is capped by more than 200 feet of the Devonian Martin Formation (Teichert, 1965).

1.3 94.3  Little Green Valley.
3.5 97.8  Outcrop along the highway of the Early to Middle Mississippian Redwall Limestone. Note the collapse breccia structures characteristic of this unit in this area. Many faults in this area complicate the structure.

0.7 98.5  Control road to Diamond Point. Proceed straight ahead.

0.5 99.0  STOP 7. Kohl Ranch fossil locality in shaly limestones and sandy mudstones of the Naco Formation. Organic remains of crinoids (stem fragments and plates), bryozoans (branching, fan-shaped and crustose), gastropods, pelecypods, productid and spiriferid brachiopods and conularids can be found here in the roadcuts on the other side of the fence (see the introduction).

0.5 99.5  Return to Control road. Turn right and proceed west.

4.4 103.9  Turn left onto the road to Diamond Point Lookout and proceed south.

3.4 107.3  STOP 8. Parking site below Diamond Point Lookout. Take walk down the dip slope of the Martin Formation (or perhaps the Redwall Limestone) for about one mile to Scout Cave. Observe the small karat sinks, tanytulas, and rattlesnakes along the route.

Scout Cave has been dissolved in the upper member of the Martin Formation (Hassemer, 1962) or perhaps in the Redwall Limestone by groundwaters percolating along a prominent joint system that trends about N78°W. This cavern system consists of a main passage about 550 feet in length and a side passage 345 feet long. The entrance slope is covered with angular, blocky rubble that collapsed from the former cave ceiling and exposed this underground cavern system. The room at the base of the entrance slope is the largest room in the cave. Flowstone features can be seen on the south wall of this room. UNDER NO CIRCUMSTANCES IS ANYONE TO PROCEED BEYOND THE ENTRANCE ROOM. DO NOT ENTER ANY SIDE PASSES!!!

REFERENCES CITED


Hasselmer, Jerry, 1962, Scout Cave (Gila County, Arizona): Cave Crawler's Gazette, v. 3, no. 8, p. 102-103.


Pewé, T. L., 1978, Guidebook to the Terraces of the lower Salt River Valley in relation to the late Cenozoic history of the Phoenix Basin: this volume.


