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Location and Chronology of Tertiary Sedimentary Deposits in Arizona

Isotopic and paleontologic dates published for 41 Tertiary sedimentary units in Arizona provide a basis for statewide correlation and interpretation for the Tertiary tectonic history of the state. Locations of the units and depositional basins are mapped, and their absolute and relative ages are plotted in a correlation chart, based primarily on isotopic dates of intercalated volcanic units.

The general stratigraphic and structural relationships of the sedimentary units provide evidence of the Tertiary evolution of structure and drainage systems in Arizona. Early Tertiary sedimentary rocks of southern Arizona are predominantly well-rounded, coarse-grained stream gravels that were derived from nearby uplands formed during the Laramide and mid-Tertiary orogenies. In northern Arizona, comparable sediments were deposited in drainage systems flowing northward from central Arizona, across the present Colorado Plateau. Local ponding occurred in both areas, wherein fine clastics and carbonates were deposited.

Extensional tectonics of the Basin and Range disturbance resulted in volcanic activity and normal faulting, creating deeply subsiding basins in which thick sequences of fluvial, lacustrine, and evaporite sediments were deposited. Sedimentation continued until Pliocene time when tectonism and volcanism abated, allowing the establishment of through-flowing drainage and downcutting of the more elevated basins. The fossil record in these basins contributes valuable information relative to their depositional history and is used for preliminary interpretations of Tertiary paleoclimates, land elevations, and paleodrainages.

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Pisoliths of Fairview Valley Formation, San Bernardino County, California

The metamorphosed Fairview Valley Formation (Permian-Triassic?) crops out beneath the Sidewinder Volcanics in the Mojave block, southern California. Abundant spherical grains occurring in its upper portions are questionably known as ooliths. However, results of field and mineralogical analyses lead to the conclusion that the majority of the grains are not ooliths but pisoliths originally formed in a sandy vadose zone. Their accretionary growth process began around siliceous nuclei in a similar manner to that of pisolith growth in caliche soil. Most of them commonly occur fused together or form unusual fitted polygonal structure.

Locally, the grains crop out as conspicuous graded, inverse graded, and lensoid or wavy beds. These are commonly separated by thin laminae composed of finely crystalline aggregates originally deposited as carbonate mud. This bedding suggests periodic accumulation under uniform, quiet-water conditions. No cross-beds or fossils were found in these deposits.

The average grain size of 466 pisoliths measured in the field ranges from 0.2 to 0.5 cm in diameter. The average size decreases vertically toward the upper (north) stratigraphic zones, which implies that either the pisoliths in the source area became smaller in size with time or they were brought from farther away. The bulk of the pisoliths is interpreted as having been carried a short distance from the source area by running water, and redeposited from waning currents similar to turbidity flows. The site of deposition was probably a nearby broad barred lagoon in proximity to a shallow marine environment, which would allow dolomitization to take place after burial of sediments.

The matrix of rock samples analyzed both by X-ray diffraction and staining contains iron-free calcite, tremolite, and forsterite. Prior to metamorphism, the matrix was possibly composed primarily of dolomite; presently, the pisoliths are formed mainly by diopside, iron-free calcite, wollastonite, dolomite, forsterite, and periclase. The calcite content in most pisoliths, especially the larger ones, seems to increase outward from the core.

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Uranium Deposits in Channel Curves of Salt Wash Sandstone Member of Morrison Formation (Late Jurassic), Utah

The Salt Wash Member of the Morrison Formation in southeastern Utah is characterized by fluvial sandstone in distinct paleochannels. The deposits are part of a large delta-fan with an apex in the vicinity of the western Grand Canyon. The exhumed channel fills, which excellently expose directional sedimentary structures, were deposited by streams of slight to moderate sinuosity, with occasional sharp bends. Such curves were loci of more conspicuous entrapment and burial of carbonaceous material. Later these areas became highly reducing environments where uranium ores precipitated from ground water percolating through permeable interconnecting channels. Major uranium deposits are more likely to occur in areas where such conditions existed.

To determine areas with strong randomness of paleocurrent directions, the vector summation method was applied to the analysis of 2,638 paleocurrent measurements. Because this method is a sensitive measure of dispersion, it was possible to outline areas displaying high and low vector strength values. Areas of high scatter commonly yield low values and polymodal distribution, and areas with low scatter are characterized by high values and unimodal distribution. Thus, areas of high channel sinuosity were successfully outlined. Major known uranium deposits occur most commonly in areas of low vector strength values. Such areas were compared with those containing known ore deposits and those considered favorable for future discoveries, and the results support the conclusion. Although the vector method has been used in many paleocurrent studies, this is the first time it has been applied in conjunction with other geologic criteria to delineate and select areas favorable for uranium exploration in sandstone deposits.

The results show an important relationship among low paleocurrent vector strength values, carbonaceous material, channel curves, and uranium occurrences in the sandstone channels.

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Palynology of Barstow Formation (Miocene), Rainbow Basin, Southern California

The Barstow Formation, a deposit of alluvial-fan, fluvial, and lacustrine sediments 3,280 to 3,940 ft (1,000 to 1,200 m) thick, was deposited in the Barstow basin during Neogene time. The formation is well exposed in the Barstow syncline about 9 mi (14 km) north of Barstow. The palynomorphs of the Bar-

stow basin were probably deposited in a wide, but relatively small, body or bodies of fresh to slightly saline water with fluctuating shorelines. The basin formed on the northern extremity of the Barstow-Bristol trough.

The most abundant palynomorphs found in the Barstow Formation belong to Asteraceae, Chenopodiaceae, *Ephedra, Eriogonum, Pinus,* and *Quercus.* Also present in lesser abundances are specimens belonging to Onagraceae, Ericaceae, *Juglans, Alnus, Carya, Arbutus, Typha,* and *Platanus.* The palynomorph assemblage is dominated by a lowland shrub community in association with an upland community of oak and pine. This association is indicative of a dry summer climate similar to, but probably wetter than, the present climate.

A middle to late Miocene age has been assigned to a vertebrate mammalian fauna near the sample locality, and radiometric dates of 13.3 to 15.9 m.y.B.P. have been obtained from local tuff beds.

The large relative abundances of *Ambrosia,* as well as the presence of *Artemisia,* indicate an age of early Pliocene for the Barstow Formation, based on present palynologic information.

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P-shooter—A Fast Seismic Source for Shallow Exploration

The P-Shooter is a new, light-weight source developed by CGG in collaboration with Shear Wave Technology Inc. Though energy is provided by a mass falling vertically, the source differs from a simple weight-drop system by its coupling device and the additional acceleration provided by a spring. It is designed to work at a very fast rate.

In operating mode the weight travels up and down a vertical tower and is guided between two rails. During the drop it is accelerated by a spring until it hits a baseplate that is coupled to the ground by part of the weight of the vehicle. After the impact and before any rebound can occur, the weight is picked up by a cable and lifted back to the top of the tower ready for a second drop.

The weight is adjustable between 250 and 500 lb. The spring provides a maximum pull of 800 lb. The combined effect of the spring and a 500-lb weight provides a total energy estimated at 9,700 joules and an impact velocity of 30 ft/sec. By comparison, the same figures for a free fall drop would be only 5,400 joules and 23 ft/sec. The time interval between two successive drops is about 3.5 seconds.

Good coupling is very important; on the P-Shooter it is achieved by a special baseplate, which is separated from the impact surface by a ball joint. This allows the baseplate to keep good contact with the ground. The baseplate is decoupled from the rest of the vehicle through rubber springs, and a hydraulic system applies a constant downforce to it. The coupling baseplate also prevents damages to a road surface.

The whole system is mounted on the back of a 4 by 4 truck. The tower can be moved forward, backward, and to some extent laterally, so that it can be vertical even when the truck is on a slope.

The following seismic properties were observed during experiments carried out in Colorado.

1. Signatures recorded on downhole phones, from 400 to 1,000 deep (120 to 300 m), near the Colorado School of Mines have an amplitude spectrum peaking at about 45 Hz, with a 12 dB attenuation at 100 Hz and a fairly steep drop above 100 Hz.

2. Bandpass analysis on a stacked section confirms that the spectrum extends up to 120 Hz at 500 ms two-way time.

3. The source is perfectly repeatable when a sufficient amount of downforce is applied to the baseplate.

4. On a 1,200% stack obtained in southeastern Colorado and shot with 10 drops per station, penetration is good down to 500 ms, below which signal strength becomes weaker.

Assuming that 20 drops per station would be enough in most areas for targets at less than 1 second, and given a rate of 3.5 seconds per drop a shot point can be completed in 2 minutes (including moving time). This means that on a normal working day, production may approach 200 shotpoints per day. With the 55-ft (17-m) spacing common in this type of work, production would be 2 mi (3.2 km) per day.

The P-Shooter is particularly appropriate for surveys that do not require resolution above 120 Hz. Since it is an inexpensive source usable with a fairly small crew, it can give good quality shallow data at a relatively low cost per mile.

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Braided-Stream and Alluvial-Fan Depositional Environment of Lower to Middle Eocene Ione Formation, Madera County, California

The lower to middle Eocene Ione Formation in southern Madera County was deposited in an alluvial-fan, braided-stream complex bordering the ancestral Sierra Nevada. Sandstone and conglomerate occur as a thin veneer unconformably overlying a deeply weathered Mesozoic igneous and metamorphic basement. Two facies are recognized: a braided-stream sandstone and a proximal to midfan conglomerate with sandstone interbeds.

Braided-stream facies display both sandstone and thin matrix-supported conglomerate (debris flows). Sandstone units contain tabular cross-bedded and parallel-laminated bedding units, which may be capped by small-scale trough cross-beds. This longitudinal-bar sequence may locally occur adjacent to large-scale festoon cross-beds of channel origin. Locally, lebensspuren (trace fossils) are abundant in the sandstone units and these traces represent biologic activity on emergent longitudinal bars or inactive channels.

The proximal to midfan facies consists of interbedded conglomerate and sandstone. Matrix-supported conglomerate units were deposited by debris flows and cross-bedded sandstone units were deposited in alluvial channels. Framework-supported conglomerate may have resulted by reworking of the sediment, removing the clay (forming sieve deposits), or as alluvial channel gravels.

The Ione Formation in Madera County is part of a long, narrow alluvial plain between the ancestral Sierra Nevada and the ocean. This part of the Ione Formation differs from the mixed marine and nonmarine environments of the Ione at its type section.

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Paleomagnetic Study of Neogene Tectonic History of Baja California, Mexico

Paleomagnetic study of 20 Miocene (19 to 5 m.y.B.P.) volcanic flows and one dike in central and southern Baja California has resulted in determination of inclinations too shallow for the present latitude at all sites, suggesting a greater amount of northward movement than can be accounted for by previous