

bayment southwest of the Defiance area during latest Givetian or earliest Frasnian time. In early Frasnian time, the Aneth Formation and unit 1 of the Jerome Member, Martin Formation, were deposited as fine-grained intertidal carbonates in northeastern and central Arizona, while the lower Temple Butte Formation carbonates formed in a more open circulation subtidal marine environment in northwestern Arizona. Between these two areas the Marble Canyon-eastern Grand Canyon area was a positive feature (here called the Grand Canyon shelf) that remained very near sea level and received little or no sediment.

By late Frasnian time depositional environments in northeastern Arizona had changed from intertidal-supratidal conditions to those of a shallow subtidal sea with restricted circulation in the east (the Elbert Formation pelleted carbonate rocks) and more open-marine circulation toward the south and west (the fossiliferous carbonate rocks of the upper Jerome Member and western Temple Butte Formation). The Grand Canyon shelf received carbonate sediments in intertidal channels and on a shallow subtidal platform to form the thin Temple Butte Formation.

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Pennsylvanian and Early Permian Paleogeography, Southern Colorado Plateau and Vicinity

Pennsylvanian and Lower Permian sedimentary rocks of the southern Colorado Plateau have been the subject of controversy concerning their correlation and origin. Paralic sediments of the Supai group (Morrowan, Atokan, Virgilian, and Wolfcampian) were deposited in the Grand Canyon embayment. A persistent southwest-trending unstable area, herein named the Sedona arch, confined all Supai sediments, except Virgilian, to the Grand Canyon and western Mogollon Rim regions; older strata are truncated by the sub-Virgilian unconformity.

Marine rocks of the Naco Group (Desmoinesian, Missourian, and Virgilian) were deposited on the Mogollon Shelf. Only Virgilian rocks cross the Sedona arch. Thus the bulk of Supai and Naco sedimentary rocks are not as closely related as most previous workers had thought.

The northwest-trending Kaibab arch provided the barrier between the Hermosa Group of the Paradox basin and the Supai and Naco to the south; therefore, most of the Supai, Naco, and Hermosa groups were deposited in distinctly separate basins.

The Wolfcampian Esplanade and Cedar Mesa Sandstone Members and Halgaito formation form a distinct eastward-thinning wedge of sedimentary rocks west of the Sedona arch. These high-energy marine shoreline and supratidal sedimentary rocks grade westward into thick marine carbonate rocks of the Cordilleran geosyncline. A widespread red-bed sequence comprising continental and possibly tidal shoreline deposits of the Hermit and Organ Rock formations was deposited across the entire study area.

The youngest sequence studied consists of sandstone, red beds, evaporites, and carbonate rocks of the Schne-

ble Hill formation and DeChelly Sandstone (Leonardian). These units are centered around the Holbrook basin and represent a complex of shallow-marine, high- and low-energy shoreline, eolian, and sabkha depositional environments. Both formations grade upward into the overlying Coconino Sandstone and related rocks.

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Applications of Probable Range Concept to Biostratigraphy

The probable range is the most frequently observed range of a taxon. Probable ranges are derived from a synthesis of local ranges characterized among a group of geologic sections. The local ranges provide the empirical biostratigraphic data from which the time and space distribution of a fossil is integrated. This distribution is approximated by the probable range.

The probable range concept is currently being applied to the biostratigraphy of many regions and is demonstrated using a North Atlantic Ocean data set of 228 species of Cenozoic and Mesozoic calcareous nannofossils occurring at 55 sites drilled by the Deep Sea Drilling Project. A major result of the application is a standardized range chart for the data set. Comparison of the range chart with published range data shows a good correlation. The rigorous application of the probable range concept sets no theoretical limits on the maximum size of a data set. This offers the potential of very high resolution and equally reliable alternatives to standard biostratigraphic zonations. The global application of the probable range concept will have a fundamental impact on the earth sciences by providing a standard biostratigraphic reference system invaluable to the interpretation of the time and paleoenvironmental relations among geologic sections.

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Distribution and Alteration of Ogallala Volcanic-Ash Deposits and Their Possible Relation to Uranium Mineralization in Western Oklahoma

Diagenesis of the Ogallala (upper Miocene-Pliocene?) and Pearlette (Pleistocene?) rhyolitic volcanic ash in western Oklahoma was studied. The Ogallala ash ranges from relatively fresh to highly altered. Chemical changes during its devitrification are characterized by a loss of silicon, sodium, potassium, and uranium, and addition of magnesium to the ash. The thorium to uranium ratios range from 4:1 to 10:1 for relatively unaltered ash to 16:1 to 64:1 for the highly altered ash. The average loss of uranium due to devitrification is greater than 3 ppm. Migration of the released uranium in the alteration system was made possible by carbonate complexing agents.

Study of the Ogallala Formation in the high plains and equivalent formations in the Gulf coastal plain indicates that these strata originally were widespread over most of Oklahoma but that the sediments were removed

from all but the western part of the state during late Pliocene-Pleistocene erosion. The volcanic-ash beds that had existed in the eroded Ogallala are a potential source for some of the uranium occurrences.

Analyses of the Pearlette ash did not disclose any alteration trends or a downward decrease in the uranium concentration. The uranium content of the Pearlette is significantly higher than that of the altered Ogallala ash. The minimum ash of the Pearlette is 0.6 m.y. which suggests that efficient release of uranium from volcanic glass, at least in some examples, is not a geologically contemporaneous process.

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Triassic Paleocaliche in Red Beds of Dolores Formation, Southwestern Colorado

Early diagenesis of Upper Triassic lacustrine mudrocks and sandstones in southwestern Colorado includes pedogenic accumulation of calcium carbonate. Petrocalcic horizons, 0.4 to 1.5 m thick, are dominated by unlaminated micritic caliche concretions which range from pellets 1 mm in diameter to nodules 30 mm in diameter. Evidence for in-situ origin of these limestone concretions includes: irregular shape, floating texture, inverse grading, and truncation of back-filled burrows.

Mature paleocaliche profiles are capped by calcium carbonate plugged horizons which contain rootlets 1 to 2 mm in diameter. These plugged horizons also contain paleofracture systems filled with reddish brown mudrock. Locally paleofracture morphology suggests plant-root control in its development. In very fine sandstones, micritic caliche nodules coalesce in upward coarsening, sinuous vertical stacks that suggest a rhizonecretion origin.

A maximum of nine petroclastic profiles were observed over a vertical interval of 56 m in one outcrop north of Durango, Colorado. The most mature profile observed exhibited the Stage III development of Gile and others. Caliche nodules and pellets occur throughout the Dolores Formation in southwestern Colorado either in pedogenic profiles or as transported clasts in fluvial, lacustrine deltaic distributary, or fan delta deposits.

Literature descriptions suggest that caliche nodules are also present in the correlative Chinle Formation of New Mexico, Arizona, Utah, and Colorado. Based on the areal distribution of modern caliche, a semiarid climate is suggested for the Late Triassic in the Four Corners region of the western United States.

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Miocene Spumellarian Radiolaria from South Pacific

The taxonomy of Radiolaria, a subclass within the phylum Protozoa, was developed by Ernest Haeckel in the late 1800s. That classification was based primarily on gross geometric patterns which have been subsequently shown to be unsatisfactory. Reclassification research has been concentrated on the Nassellarian (conical)

radiolaria because of more pronounced characters. Spumellarian (spherical) radiolaria, however, have not been regrouped mainly because their morphology is more subtle and difficult. However, they are the most robust and most persistent in the fossil record (Ordovician to present), and therefore the likeliest to be preserved in strata.

Two core sites, 77B and 289 from the Deep Sea Drilling Project, provide a continuous time sequence during the Miocene and both probably represent a stable equatorial current system. Slides were made at 1-m intervals from the cores and spumellaria individuals were studied from successive time sequences. Nineteen characters were recorded for each and then subjected to a rigorous analytical technique provided by a numerical taxonomy program (NTPAC-11). Pearson's correlation coefficients detected 23 species throughout the Miocene. An unweighted pair group clustering method using arithmetic averages grouped these species into 14 genera.

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Calcium Budget in Frio Sandstones, Southwest Texas

Studies of active burial diagenesis in Frio (Oligocene) sandstones in the temperature range 90 to 160°C (burial depth, 2,500 to 4,450 m), combined with other studies at lower temperatures, show important sources and sinks for calcium. The main calcium sources are conversion of smectite to illite (40 to >150°C), pressure solution of detrital micrite (<90°C), albitization of calcic plagioclase (100 to 120°C), and to a lesser extent devitrification of acidic volcanic glass (<90°C).

The main calcium sink is cement-forming calcite. The composition of the calcite appears to reflect the various sources, thus calcite cement from the breakdown of smectite shows a late-stage iron-magnesium enrichment, whereas calcite replacing albitized plagioclase is nearly pure calcite. Another sink for calcium, previously undescribed for the Gulf Coast Tertiary, is authigenic sphene which is found at temperatures greater than 150°C.

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Signature Processing of North Sea Air-Gun Data

Results of development drilling on a North Sea oil field suggested that the actual structure was much more complex than the original interpretation. We present the results of a reprocessing project on selected seismic lines over the structure. The original data were recorded using a variable cable depth and a deep tow hydrophone for the gun signatures. The data were reprocessed using only signature correction to a zero-phase wavelet. However, results obtained at the horizon of interest were still affected by cable ghosts, frequency attenuation within the overlying sediments, and practical constraints on the recording of the source ghost.

Because the purpose of the project was to improve delineation of very small faults, we decided to try to improve resolution by applying corrections for these effects. The initial tests were done by designing and ap-