

faults then wrap around the northeast side of the Awawatz Mountains and thrust the diorite northeastward over Quaternary alluvial fan gravel. The gravel is in turn telescoped by other reverse faults that lie within the southeastern extension of the Death Valley fault zone.

In view of the evidence for compressional strain on the east side of the Awawatz Mountains and the apparent lack of youthful Garlock traces east of the Death Valley fault zone, we conclude that the Garlock fault terminates in the Awawatz Mountains and that the east side of the Awawatz Mountains is bounded by the west-dipping reverse faults as hypothesized by Hewett in 1955.

#### CULTURE AND CLIMATIC CHANGE IN NORTH CENTRAL MEXICO

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Climatic changes have been inferred from the archaeological data in north central Mexico. A lacustrine sediment core was extracted from a crater lake near Valle de Santiago, Guanajuato, Mexico in order to reconstruct paleoenvironmental changes through pollen analysis. The sediments of this core have been well dated and render a basal age of ca. 11,000 B.P. Changes in the sedimentation rate and composition of taxa, specifically, the ratios of non-arboreal to arboreal pollen, indicate a heavy human occupation, and by inference, the introduction of agriculture after 2600 B.P.

#### GEOLOGIA Y PALEONTOLOGIA DE LA SIERRA STA. CRISTINA, ESTADO DE ZACATECAS, MEXICO

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La Sierra Santa Cristina se localiza al suroeste de la Estación Camacho, en el cruce de las coordenadas 102°30' de longitud oeste y 24° 23' de latitud norte. Está constituida por 4 pliegues pequeños recostados hacia el norte, con una longitud aproximada de 9 km y una anchura de 2.5 km.

La secuencia estratigráfica está representada por 3 formaciones: La Caliza Cuesta del Cura, del Albano que consiste en capas delgadas de calizas de color gris-mediano, ondulantes, con nódulos y horizontes pequeños de pedernal negro. Suprayace a esta unidad, la Formación Indidura del Cenomaniano-Turoniano y se presenta como una secuencia que, en su base, consiste en caliza arcillosa de color gris mediano que interperiza a color amarillento; hacia la cima, esta formación se hace más arcillosa, pero al aproximarse al contacto con la Formación Caracol, termina con una secuencia de lutitas de color negro. En esta unidad se colectó una abundante fauna formada por numerosos ejemplares de Inocerámidos (*Inoceramus concentricus* Parkinson; *I. crippsi* (Mantell); *I. (Inoceramus) cycloides* Wagner; *I. (Cremnoceramus) inconstans* Woods; *I. (Mytiloides) labiatus* (Scholotheim); *I. lingua* Goldfuss; *I. opalensis* Boese e *I. pictus* Sowerby).

La última de las unidades que aflora en el área es la Formación Caracol de edad senoniana, tiene más de 300 m de espesor de lutitas y limolitas y, en su cima, contiene capas gruesas de arenisca.

#### FREQUENCIES AND MAGNITUDES OF SURFACE RUPTURE ALONG THE PITAYCACHI FAULT, NORTHEASTERN SONORA, MEXICO

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In 1887, surface rupture occurred on 100 km of the Pitaycachi normal fault forming a 2 to 4 m scarp along previous traces of surface rupture. After a century of erosion, debris slopes are common at the base of the scarp and near vertical free faces are still present in bedrock and carbonate-cemented gravel, but scarps in sandy alluvium generally have been eroded to 10° to 20° wash slopes.

Several lines of evidence indicate at least 10<sup>5</sup> years between major surface ruptures on the Pitaycachi fault. Parts of the fault are down-slope from a pedimented and embayed but continuous mountain front. Prior to the 1887 earthquake, the fault trace was partly concealed by late Pleistocene and Holocene alluvial geomorphic surfaces. The calcic soil horizon in a paleargid of one of these surfaces is offset the same amount as the 1887 scarp height. Along the piedmont reach of the Rio Jucural, a valley 1 to 2 km wide and 38 m deep has two Pleistocene and one Holocene stream terraces that were not ruptured prior to 1887. The pre-1887 scarps cut multiple alluvial geomorphic surfaces of probable mid- to late-Pleistocene age with cumulatively greater displacement on surfaces with increasing age. These older scarps had been eroded to 3° to 6° wash slopes prior to the 1887 event even where resistant volcanic gravels are present. Although the magnitudes of several Quaternary surface ruptures appear to be about 2 to 4 m, our preliminary work indicates that the total amount of late Quaternary uplift is an order of magnitude less than that for normal faults in tectonically active areas of Nevada and California.

#### SILICIC ASH-FLOW TUFFS INTERBEDDED WITH SUBMARINE ANDESITIC AND SEDIMENTARY ROCKS IN LOWER MESOZOIC ROOF PENDANTS, SIERRA NEVADA, CALIFORNIA

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Rhyolitic to andesitic pyroclastic rocks and lava flows are interstratified with shallow marine quartzites and carbonates in a sequence >10 km thick in the southern Sierra Nevada, CA. The andesites and nonvolcanic sedimentary rocks show features indicative of shallow marine deposition, while interstratified voluminous silicic tuffs have features similar to subareal ash-flow tuffs. Seven tabular units of rhyolitic and dacitic pyroclastic rocks (some > 800 m thick) are interpreted as ash-flow tuffs. These are massive, unsorted, monolithologic, pumice-rich, and show systematic changes in pumice flattening apparently related to cooling history rather than tectonic deformation. Some of the thicker tuffs contain megabreccias (clast size < 200 meters) suggesting deposition as caldera fill. All of these features have been described elsewhere in subareally emplaced ash-flow tuffs. However, some of the thick ash-flow tuffs in the southern Sierra Nevada differ from subareal ash-flow tuffs by passing gradationally upward into bedded sequences of well-sorted ash, lapilli and block layers. Andesitic units are far less homogeneous and voluminous than the silicic units. Sorting, grading of single beds or overall grading of bedded sequences, and soft-sediment deformation are recognized within sections of massive monolithologic andesitic tuff breccias and lavas; these features are considered typical of subaqueous volcanism. Possible interpretations of the observed relationships include: (1) complete displacement of the shallow water column by voluminous silicic eruptions or (2) minimal interaction with water during deposition of silicic ash-flows or (3) regional tumescence prior to each ash-flow eruption resulting in periodic changes from shallow marine to subareal deposition.

#### EVIDENCE FOR HIGHER STANDS OF PLEISTOCENE LAKE MANLY, SOUTHERN DEATH VALLEY, CALIFORNIA AND A POSSIBLE DRAINAGE CONNECTION TO THE COLORADO RIVER

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The commonly accepted high stand for Lake Manly in Death Valley is approximately 600 feet above sea level. This is based primarily on the presence of wave-cut terraces on Shoreline Butte whose crest, however, is only 648 feet above sea level. New evidence for higher shorelines has been found above 900 feet along the north front of the Awawatz Mountains in southern Death Valley. This evidence includes partly dissolved quartzite cobbles, possible tufa mounds, and wave-built terraces. Evidence for wave-built terraces is clear; the tufa mounds may have formed as spring deposits; the cause of the partial solution of the quartzite cobbles is unclear. However, these cobbles are associated with unambiguous lake sediments and wave-cut shorelines at approximately 600 feet in the Salt Spring hills, which are adjacent to the north front of the Awawatz. All the shorelines throughout the region are still horizontal.

It has been suggested that the Death Valley drainage system may have been connected to the Colorado drainage basin at some time in the Quaternary. This suggestion is based primarily on isolated occurrences of pupfish (*Cyprinodon*) in the Colorado River drainage, Death Valley, and the Amargosa River valley. No direct evidence has been found heretofore to substantiate the connection. However, if Lake Manly were filled higher than 900 feet above sea level, it could have drained to the south and thus made a connection with the Colorado River drainage basin.

#### TECTONIC GEOMORPHOLOGY OF QUATERNARY FAULT SCARPS, SANTA RITA MOUNTAINS SOUTHEASTERN ARIZONA

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A discontinuous zone of subdued fault scarps offset 40 km of Quaternary alluvium on the western piedmont of the Santa Rita Mountains. The scarps trend N-S to NE-SW and are subparallel to, and 1-7 km basinward from, the highly embayed but continuous mountain front. Scarp heights range from 1.5 to 5 m. Maximum scarp slope angles range from 3° to 9°, depending on scarp height. Shear zones associated with some scarps indicate high angle normal faulting. Small-scale grabens have been inferred from topographic scarp profiles and one graben-forming antithetic fault is exposed. Locally, bedrock exposures and Inselbergs occur near the fault zone on the mountainward side, but none have been observed on the downthrown side.

Preliminary Quaternary geologic mapping, longitudinal topographic scarp profiles, and soil descriptions indicate that a substantial length of time has elapsed since major surface rupture. Faulted geomorphic surfaces with paleargid and paleorthid soils appear to be mid- and late Pleistocene in age. Surfaces with weakly to moderately developed soils (haplargids, calciorthids and torrifluvents), inferred to be latest Pleistocene and Holocene in age, are not ruptured. Comparing our data with Bucknam and Anderson's (1979) empirical relationship between scarp morphology and scarp age, the scarps appear to be approximately 10<sup>5</sup> years old, assuming only one movement along the faults. However, mid-Pleistocene surfaces may be offset more than late Pleistocene surfaces. Trenching and further topographic profiling will quantify these relationships.