Outcrop Geology of Plio-Pleistocene Strata of the Confidence Hills, Southern Death Valley, California

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ABSTRACT

The Confidence Hills, Southern Death Valley, California, are composed of Plio-Pleistocene lacustrine beds, evaporite beds, ashes, playa sediments, alluvial fan and fluvial deposits. The sediments have been divided into 5 mappable units. From oldest to, youngest, they are: the Confidence Hills "formation" (informal) composed of three interfingering members, and overlying Units A and B which do not exhibit transitional contacts with either underlying units or with themselves. The Confidence Hills formation includes the lacustrine and playa fine sands, and silts and clays of fluvial sediments. The lower two members are characterized by the presence of anhydrite. This formation also contains at least 15 volcanic ashes useful for determining age and correlation. Unit B is a red-to-brown coarse fanglomerate that lies disconformably above the Confidence Hills formation. Unit A, a second fanglomerate deposit, overlies the other units in a prominent angular unconformity. The southernmost canyon was studied in greater detail, both lithostratigraphically and magnetostratigraphically (Beratan and Murray, and Pluhar et al., this volume). There are two primary structural features in the Confidence Hills: the Southern Death Valley fault zone and a large anticlinorium which makes up the Confidence Hills.

INTRODUCTION

The Plio-Pleistocene boundary is of great interest because of the accompanying change of global climate. In the Confidence Hills, Death Valley, California, a sequence of Plio-Pleistocene pluvial lake sediments are exposed that afford an unusually detailed record of this time interval. Preliminary paleomagnetic work indicates that these sediments have a very high deposition rate of about 25 cm per thousand years, much higher than most other marine or terrestrial records (Pluhar et al., 1991). Not only are the paleomagnetic signatures preserved, but there is also an excellently preserved, highly detailed sedimentary record. Thus, there is the possibility that signatures of climatic change are also well preserved in the sediments. Herein we subdivide the Plio-Pleistocene strata into units that can be correlated between the E-W watercourses that cut the generally N-S anticlinal structure. A preliminary outcrop map illustrating these subdivisions is included. Companion papers (Pluhar et al. and Beratan and Murray, this volume) discuss the sedimentological and paleomagnetic records of this locality.

REGIONAL GEOLOGY

The Confidence Hills are situated in Southern Death Valley (Figure 1), which is part of the Western Great Basin (Basin and Range province). Death Valley has been a rapidly subsiding basin at least since Pliocene times. As such, it has been the final resting place at times for waters draining the east slope of the Sierra Nevada, the north slope of the Transverse Ranges, the Mojave Desert and the Southwestern Nevada Desert. During the Pleistocene, waters from the Sierra Nevadas drained into Lake Owens which spilled into Lake China and subsequently into Lake Searles, Lake Panamint and finally into Lake Manly (Smith and Street-Perrott, 1983). From the Mojave area, waters drained from the Mojave River into Lake Manix which overflowed to Death Valley (Morrison, 1991). This drainage apparently began less than one million years ago (Nagy and Murray, 1991). The Amargosa River has brought waters and sediments to Lake Tecopa from the Nevada Desert, and since 160,000 years ago also into Death Valley (Morrison, 1991).

The Plio-Pleistocene sediments of Confidence Hills are situated between two branches of the Southern Death Valley Fault Zone. These are left stepping, right-lateral faults (Troxel and Butler, 1986). The strata contain a seemingly continuous record, dated through magnetostratigraphy and tephrachronology, covering an interval from at least 2.2 Ma to less than 1.5 Ma. They consist of fine-grained clastics and anhydrite/gypsurn beds deposited in a lacustrine to playa setting, sandstones and conglomerates deposited in a fluvial to alluvial fan setting, and volcanic ashes (Beratan and Murray, this volume). The Plio-Pleistocene sequence forms a series of NW-SE trending folds that are part of a large anticlinorium.

This paper presents the results of detailed mapping in the Confidence Hills. Specifically, the southernmost throughgoing canyon, informally referred to as "Confusion Canyon" (canyon #1 on Plate 1) was most closely investigated in both lithostratigraphy and magnetostratigraphy (see Beratan and Murray, and Pluhar et al., this issue).

The Confidence Hills are reached by travelling on California State Highway 178 westward from Shoshone until a "T" junction is reached with a gravel road which heads south on the floor of Death Valley. The hills to the west of this junction are the Confidence Hills. Mapping proceeded from the south end, where the first throughgoing watercourse occurs (canyon #1), towards the north.

GEOLOGY
Stratigraphy

The Plio-Pleistocene rocks in the area have been divided into five distinct units (in order of relative ageoldest to youngest): the Confidence Hills "formation" (informally defined) composed of three interfingering members, and overlying units B and A which do not exhibit transitional contacts. We here use the term "formation" in an informal sense here and plan to propose it formally in a later paper.

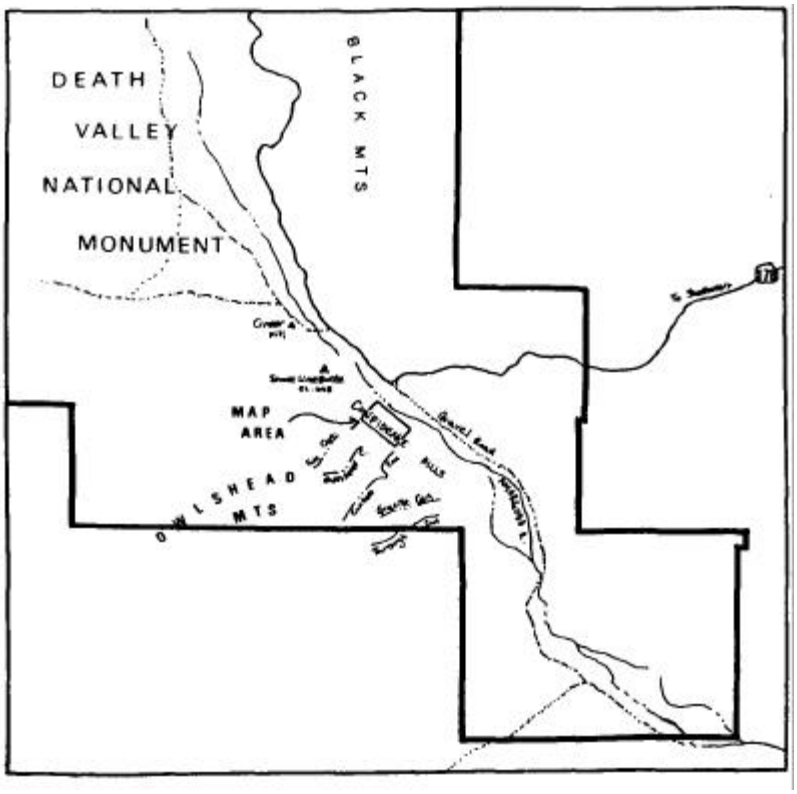

Figure 1. Location Map (modified from Guide to *Death Valley,* Automobile Club of Southern California)

Confidence Hills formation.

This formation comprises most of the Confidence Hills and almost entirely that part of the hills to the east of the western branch of the Southern Death Valley fault zone. Depositional units include fine sands, silts and clays, as well as conspicuous anhydrites. These are interpreted as lacustrine, playa and fluvial sediments and are used to distinguish some of the different members of the formation. The sediments in Confusion Canyon also contain at least fifteen volcanic ashes; additional ashes are found in the northwest sector of the map area. The Huckleberry Ridge ash (Troxel et al., 1986) from the caldera in the Yellowstone National Park area (ca. 2.0 Ma) (Izett, 1981) is particularly useful as an initial constraint on the age. Pluhar et al. (1991) combined the paleomagnetic signatures of the Olduvai subchron with the age of the Huckleberry Ridge ash to derive an average deposition rate of 25 cm/1000 yrs. A more detailed stratigraphic section of this formation in Confusion Canyon is discussed in Beratan and Murray (this volume), and updated paleomagnetic information is provided by Pluhar et al (this volume).

The lower member of the Confidence Hills formation includes both banded and massive anhydrite beds as well as fine silts and clays. The vertically dipping, massive anhydrite beds are especially resistant and form ridgetops which provide local marker horizons. This member is exposed by the anticlinal structure only in the canyons on the southern map area. No older rock units have been recognized by us in the Confidence Hills. Dooley and McClay (1992) recognize an underlying halite layer, which is evident by Karst topography locally.

The middle member contains banded anhydrite and fine sands in the south. Towards the north, this member exhibits less sand and more silt and clay-rich facies, but still exhibits the banded anhydrite. Desiccation cracks and halite crystal casts found within the middle member imply that it was subaerially exposed at times. The contact between the middle and the lower member is gradational and defined by the top of the highest massive anhydrite bed which is found at the 30 m level in the Beratan and Murray section (this volume). The middle unit contains the Huckleberry Ridge ash and many other ashes, both grey and white. The Huckleberry Ridge ash is easily distinguished by its thickness, about 40 cm, and grey color, and provides a good marker bed in the southern canyons.

The upper member is distinguished from the lower two in that it contains no banded anhydrite. It consists of red-brown fine-grained sand and silt, as well as one isolated massive anhydrite bed which provides a good marker bed in these younger strata. The contact between this unit and the middle member is placed at the highest banded anhydrite in the

section (at 187.3 m in the Beratan and Murray section, this volume). The sands near the contact are both red and green in color and are reasonably well sorted. To the north, this unit is thicker and includes ash layers and paleosols.

A facies containing volcanic clasts, primarily basalts, is interbedded within the middle member of the Confidence Hills formation; it is exposed only in the northwestern part of the map area and thins abruptly to the south. It is indurated with a fine- to coarse-grained sandy matrix. The matrix is dark in color, similar to the clasts, which implies that it may have been derived from the same basaltic source. The conglomerate appears to have been deposited in the southerly, distal portion of a fan which grades laterally into stream-reworked sediments. This facies may correspond stratigraphically to layers containing thin lenses of fine grained sandy basaltic clasts in the southeastern canyons (e.g. at 162 m in the Beratan and Murray section, this volume). Pleistocene basalts, just north of the Confidence Hills at Shoreline Butte, may be the source of the volcanic clasts.

Unit B

Unit B, an alluvial fan deposit, is dominated by redto-brown coarse-grained sand interlayered with conglomerate. The coarse fraction contains rounded pebble- to cobble-sized clasts and rare, large clasts up to about 2m in diameter. The clasts are predominantly granitic with some reddish volcanics. The sand matrix is also red-to-brown. The source of most of these lithologies is believed to be in the Owlshead Mountains to the Northwest (Troxel and Butler, 1986). Unit B also contains several thin ash beds. A disconformable contact is present between this unit and the Confidence Hills formation, even though the beds locally appear conformable in some areas. Unit B truncates the Confidence Hills formation in the southern portion of the map area, and part of the upper member is not present there. Furthermore, the dip of Unit B shallows abruptly at the contact with the upper member of the Confidence Hills formation at several locations.

Unit A

Unit A, a younger fanglomerate deposit, overlies the other rock units in a prominent angular unconformity. This unconformity is quite visible in Confusion Canyon, where it truncates Unit B. To the north, Unit A is present as a thin discrete layer, varying from 1 to 3 m.. Clasts are primarily granitic with some basalt. Unit A exhibits an overall grey color in contrast to the reddish color of Unit **B.**

Structure

There are two primary structural features in the Confidence Hills. The first is the Southern Death Valley fault zone, and the second is the large anticlinorium which makes up the Confidence Hills.

The Southern Death Valley fault zone the Confidence Hills. The western branch of the fault crosses the west side of the hills and is believed to be a left step from the branch further south (Troxel and Butler, 1986). This western branch can be identified by linear gullies and aligned saddles. The eastern branch is thought to run through the Amargosa River channel (Troxel and Butler, 1986). Within the fault zone, smaller faults were found striking parallel to the trace of the main fault. These faults, however, show a normal dip-slip component of motion. The Confidence Hills have been interpreted as forming through transpression as a result of the left step in the right lateral fault system (Troxel and Butler, 1986), although the absence of prominent rotations in the paleomagnetic data (Pluhar et al., this volume) introduces a new element into any tectonic interpretation.

The large asymmetrical anticlinorium runs through the Confidence Hills with the axis trending almost parallel to the fault in the southern section but turning more northward in the northern section. Beds near the top of the anticlinorium show overturned, isoclinal, chevron folds, some with sub-horizontal axial planes; this may indicate low overburden at the time of folding. Salt has been reported as being involved in the core of the anticlinorium (Dooley and McClay, 1992). We noticed a salt bloom after heavy rains and some karst-like topography exposed at the west end of Canyons 1 and 2, on the east side of the west branch of the Southern Death Valley fault trace.

The anticlinorium is comprised of two plunging anticlines which converge in the middle of the structure, giving an hourglass shape to the sedimentary contacts. The southern anticline plunges to the northwest and the northern anticline plunges to the southeast. Another large syncline and anticline with axes trending parallel to the fault in the southern section of the map, crops out through the alluvium to the east.

METHODS

Conventional geological mapping was carried out on a composite of USGS topographic maps. These include the 7.5 minute series of the Shoreline Butte, Confidence Hills West and Confidence Hills East quadrangles. This map was then enlarged to match the scale of aerial photographs (USGS Eros Data Center). Map units show up distinctly as dark and light areas which are very useful in correlating over long distances. Key horizons were traced along strike to verify structural orientation. Enhanced LandSat images (provided by R.G. Blom, Jet Propulsion Laboratory) confirmed the outline of the units, especially the lower and middle members of the Confidence Hills formation.

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REFERENCES

Beratan, K. and Murray, B., 1992. Stratigraphy and Depositional Environments, Southern Confidence Hills, Death Valley, California. San Bernardino County Museum Association Quarterly, 39(2). Mojave Desert Quaternary Research Symposium: this volume.

Butler, P.R., 1984. Geology, Structural History, and Fluvial Geomorphology of the Southern Death Valley Fault Zone, Inyo and San Bernardino Counties, California. Ph. D. thesis, Univ. of Calif.- Davis.

Dooley, T. and McClay, D.R., 1992. Transpressional Deformation along the Southern Death Valley Fault Zone, California. submitted to Geol. Soc. Am. Bulletin.

Izett, G.A., 1981. Volcanic Ash beds, Recorders of Upper Cenozoic Silicic Pyroclastic Volcanoes in Western United States. J. of Geophys. Research, 86(B11): p. 10200-10222.

Morrison, R.B., 1991. Quaternary Stratigraphic, Hydrologic and Climatic History of the Great Basin, with Emphasis on Lakes Lahontan, Bonneville and Tecopa, in The Geology of North America, K-2: Quaternary non-glacial geology: Conterminous U.S., Geol. Soc. of Am.: p. 283-320.

Nagy, E.A., and Murray, B.C., 1991. Stratigraphy and Intra-Basin Correlation of the Mojave River Formation, Central Mojave Desert, California. San Bernardino County Museum Association Quarterly, 38(2). Mojave Desert Quaternary Research Symposium: p. 5-30.

Pluhar, C.J., Kirschvink, J.L, and Adams, R.W., 1991. Magnetostratigraphy and Clockwise Rotation of the Plio-Pleistocene Mojave River Formation, Central Mojave Desert, California. San Bernardino County Museum Association Quarterly, 38(2). Mojave Desert Quaternary Research Symposium: p.31-42.

Pluhar, C.J, Holt, J., Kirschvink, J., and Adams, R. 1992. Magnetostratigraphy of the Confidence Hills formation, Southern Death Valley, California. San Bernardino County Museum Association Quarterly, 39(2). Mojave Desert Quaternary Research Symposium: this volume.

Smith, G.I. and Street-Perrott, F.A., 1983. Pluvial Lakes of the Western United States in Porter, S.C., ed., The Late Pleistocene, v.1: Minneapolis, Univ. of Minnesota Press: p. 190-212.

Troxel, B. and Butler, P.R., 1986. Multiple Quaternary Deformation,, Central Part of the Confidence Hills, Death Valley, California: an Example of Folding Along a Strike-slip Fault Zone, in Quaternary Tectonics of Southern Death Valley, California, Friends of the Pleistocene, Pacific Cell, 1986 Field Guide.

Troxel, B. , Sarna-Wojcicki, A.M. and Meryer, C.E., 1986. Ages, Correlations and Sources of Three Ash Beds in Deformed Pleistocene Beds, Confidence Hills, Death Valley, California, in Quaternary Tectonics of Southern Death Valley, California, Friends of the Pleistocene, Pacific Cell, 1986 Field Guide.