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FIELD GEOPHYSICAL TRAINING OF ASTRONAUTS IN TAOS VALLEY – A BRIEF SYNOPSIS

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Abstract.—Astronaut teams acquired ~16 km of gravity data during a planetary exploration simulation conducted in the vicinity of Taos, New Mexico. In the course of the investigation, a previously unsuspected fault - the Pingüino fault - with hundreds of meters of displacement was discovered. The gravimetric survey (summer, 1999) was the first phase of a geophysical assessment of the ground-water resources around Taos, an area of rapid population growth, and it was executed to help delineate buried structures that significantly influence ground-water flow and accumulation in the valley. Participants in the investigation learned a technique with direct relevance for lunar and planetary exploration and acquired data that were incorporated into subsurface geological and hydrological models of Taos valley.

INTRODUCTION

For human exploration of the solar system, instruments must meet criteria of safe operation, of low mass, volume and power demand, and of ruggedness and reliability (Meyer et al., 1995; Hoffman and Kaplan, 1997; Budden, 1999). Tools will be selected for addressing fundamental scientific questions as well as for identifying resources — particularly water — and determining their distribution. Gravity surveying is passive — that is, no energy must be put into the ground in order to acquire data, and the small portable instruments are well suited for walking traverses or for operation from a rover.

In the Taos valley, large faults that control ground-water distribution in the subsurface lie buried beneath sediments shed from the Sangre de Cristo range (Figs. 1, 2); geophysical methods provide the means to see through that sedimentary cover. In preparation for the geophysical exercise, field trials were conducted with both gravity and seismic reflection instruments; however, time was not sufficient to execute both types of surveys concurrently.

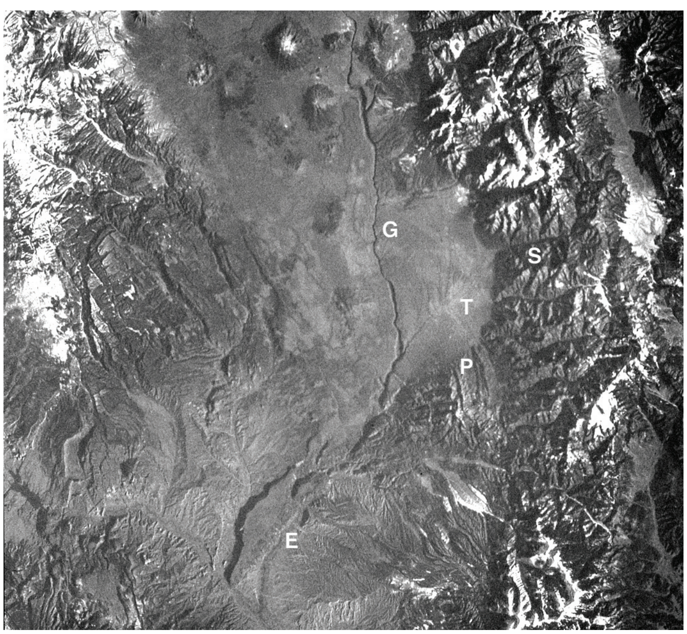

FIGURE 1. Photo STS027-44-66 of Taos valley (T), locale for the gravity survey. Sangre de Cristo range (S), Rio Grande gorge (G), Embudo transfer fault zone (E) (Muehlberger, 1979), and Picuris-Pecos fault system (P). (NASA photo, Johnson Space Center, Earth Science & Image Analysis Laboratory; <http://eol.jsc.nasa.gov>)

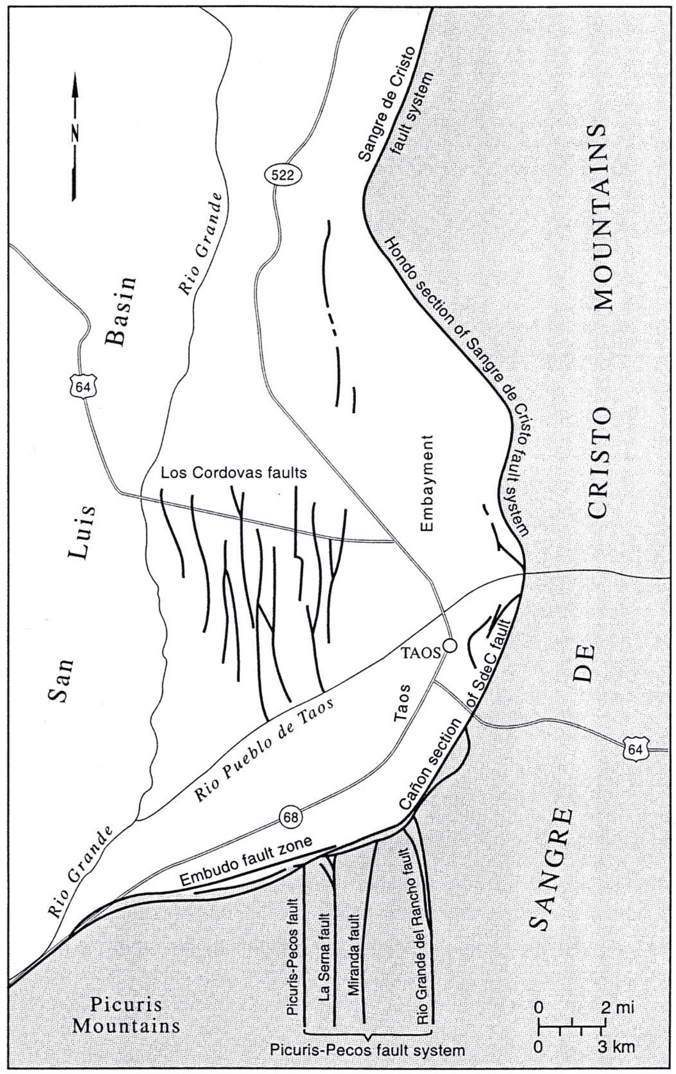

FIGURE 2. Generalized structural geology of Taos area, San Luis valley (Bauer, Johnson and Kelson, 1999, fig. 1). Gravity data were collected in Taos from just west of NM 68, eastward to the Sangre de Cristo fault system.

Additionally, the use of a shotgun seismic energy source required filling each shot hole with water (for best transmission of energy into the subsurface), and the ballistic source itself rendered that method unrealistic for a NASA planetary exploration simulation.

The known geology and hydrology (Bauer et al., 1999; Johnson, 1999) of the site and the probable magnitude of the buried faults suggested that a gravity survey, a technique utilized on the Moon, would provide needed data on the large buried structures. The contrast in density between bedrock (Precambrian metamorphic rock and massive Carboniferous limestone) versus unconsolidated valley sediment would permit definition of faults that juxtapose the two.

METHOD

Field instruction by W. R. Muehlberger on Rio Grande rift structure, stratigraphy, and volcanism – an element of astronaut geological training since the Apollo missions to the Moon (see Muehlberger, 2004, this volume) – set the stage for geophysical investigations of the rift basin margin. The class was divided into four field crews, each of which was then briefed on the scientific objectives and on the procedures for gravimetric surveying. In the field, the stations where gravity readings would be taken were located by means of laser rangefinder, newly flown aerial photographs, and detailed topographic maps. Accurate and precise elevations, critical for terrain corrections to gravimetric data were determined by NMBG geoscientists, and gravimeters were regularly recalibrated. Field station locations and gravimeter readings were radioed to "Mars Base" (a graduate student with a laptop computer in a pickup truck). The data were processed in real time by geophysics graduate students from New Mexico Institute of Technology (Fig. 3). The next morning, each crew viewed the profile that they had acquired, participated in its interpretation, saw the data entered on the Bureau map, and helped select the location for the traverse to be executed by the next group.

RESULTS

Fidelity of the exploration simulation depended upon the application of space-proven instruments to solve a real scientific problem (Fig. 4). Not only did data from this gravity survey define buried faults that had been identified on the basis of surface mapping, but a previously unsuspected fault with hundreds of meters of displacement was also discovered (Fig. 5). The orientation and magnitude of the fault were delineated in successive profiles, and the structure was mapped and named. [Taos valley is thousands of kilometers from either pole, and users of the map might wonder about the naming of the Pingüino fault - its surveyors/discoverers were the astronaut class whose monicker was "the Penguins."] That fault and other geophysically defined structures directly influence ground-water movement, as well as the extent of potential sedimentary aquifers in the valley; this survey provided important new data for the project.

As soon as the ~16 km of precise and accurate gravity data acquired by the group had been processed, they were incorporated into subsurface geologic and hydrogeologic models of Taos valley (Bauer et al., 2000), an area where there are serious concerns about ground-water resources. The investigation helps provide the framework for estimates of ground water storage and recharge, which will then furnish planners and politicians hard numbers for water-resource management.

This survey provided real data for addressing a pressing societal problem — it was not "make-work". As noted by Gregory Chamitoff, the gravity survey "…was an invaluable part of the entire field trip. Too much of our learning is passive, and this activity really got us completely involved in the science. In fact,

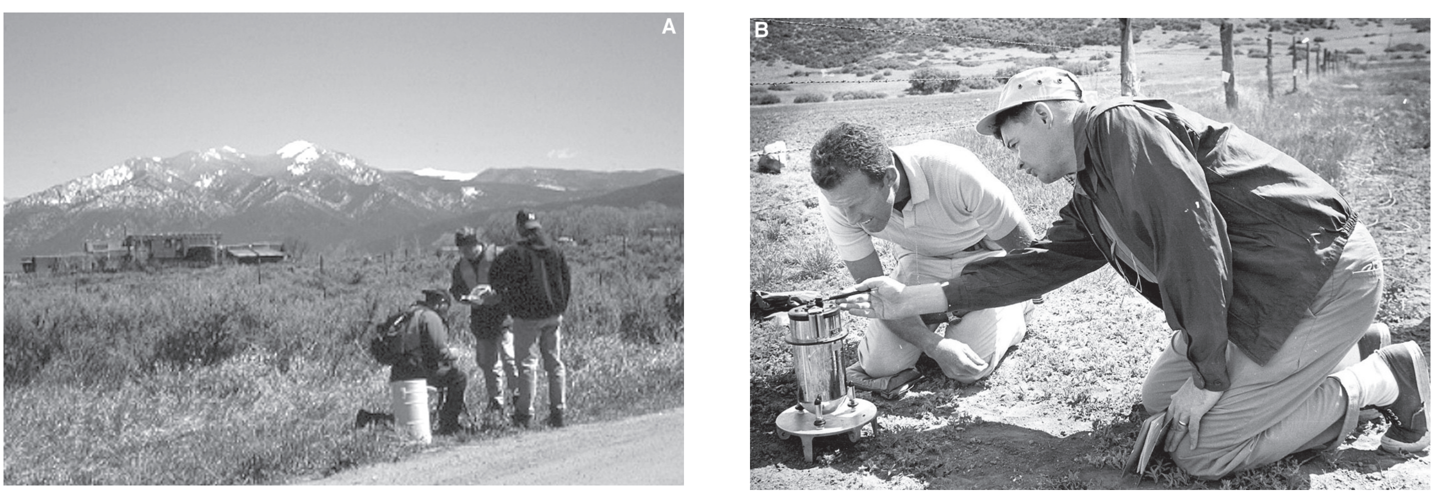

FIGURE 3. **A.** Hans Schlegel and Clay Anderson, coached by Tony Lupo (New Mexico Institute of Technology), take a gravity reading at a station northeast of Ranchos de Taos. **B.** Astronaut Gordon Cooper and U.S.G.S. geologist Marty Kane use a gravimeter during Apollo mission training (Schaber, 2002).

Figure 4. John Young, Commander of Apollo 16 (with gravimeter), and James Reilly, current geologist astronaut (right), assess the relevance of the simulation. W. R. Muehlberger (center) instructs as D. L. Ross, Leo Eyharts, and Lee Archambault (left to right) observe.

I think this could be expanded to using other instruments similar to the types we would use on the Moon or Mars".

SUMMARY

Thirty-one members of the 1998 astronaut candidate class are now experienced in collecting gravity data to define buried faults in the context of a ground-water investigation. All readily mastered the technique and recognized the potential of the method for planetary exploration — particularly of Mars, where windblown sand mantles varied terrain and where significant structures may lie beneath unconsolidated sediment.

One or more of these individuals may step on Mars or Earth's Moon, but most will help direct those missions from Earth. All will know at least one investigative technique, they will have helped plan a geophysical traverse, and they will have a sense of the time required for scientifically rigorous planetary exploration.

Future geological and geophysical training will build upon this experience and address differing scientific objectives, as data from the Mars Exploration Rovers are evaluated and as candidate sites for lunar and martian exploration are selected. Additional geophysical investigations are planned in summer, 2004 for the astronaut class of 2000 whose field training had been postponed. Seismic profiling, for which field trials were conducted prior to the 1999 exercise, is another geophysical technique that could reveal much about the subsurface structure and stratigraphy of other planetary bodies. In addition an exercise in sampling and analyzing spring waters, as well as ancient and modern spring deposits, has now been developed in preparation for seeking water and possible biota on Mars. Regarding this initial geophysical exploration simulation, we hope that we have contributed to building an exploration culture within and beyond NASA and to preparing explorers for the task.

ACKNOWLEDGMENTS

Without the expertise and vision of many explorers this investigation could not have been conducted at all, much less successfully: Bill Muehlberger (University of Texas at Austin) in particular; John Young, George Abbey, and Duane Ross (NASA-Johnson Space Center); Paul Bauer, Peggy Johnson, Adam Read and coworkers (NM Bureau of Geology); Harold Tobin and Tony Lupo (NM Tech). Fiscal support was received from [then] Office of Earth Sciences management (NASA-JSC/Lockheed-Martin), as the field exercise was ready for launch. The Penguins, of course, made it fly. Just as there would have been no gravity survey without the efforts of numerous colleagues, there would have been no synopsis for this volume without the suggestions of Bill Muehlberger, Brian Brister, and Greer Price.

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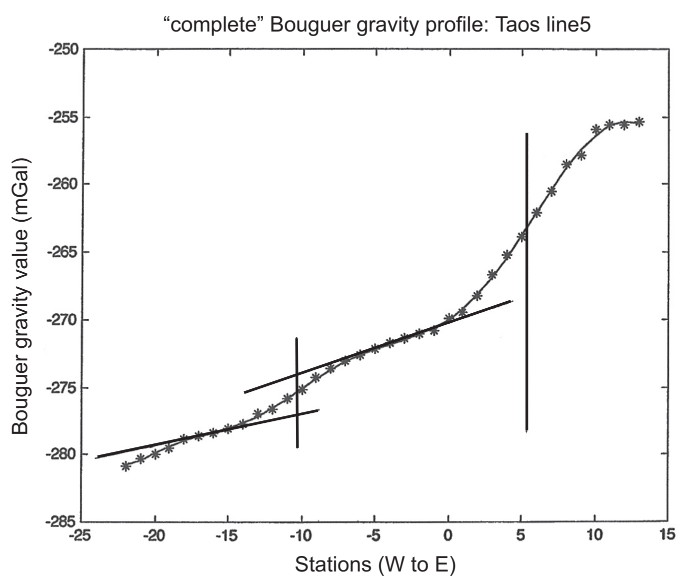

FIGURE 5. Bouguer gravity profile from Taos survey. The Pingüino fault, which juxtaposes dense Precambrian metamorphic rocks and Carboniferous limestones (east) and unconsolidated rift-basin sediments (west), is expressed as a marked steepening (12 mgal offset) of the profile near gravity station 5. The smaller fault (3 mgal offset) to the west was previously known.

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