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PROPOSED SEISMIC REFLECTION PROFILING ON PAJARITO PLATEAU, LOS ALAMOS COUNTRY, NEW MEXICO

Abstract

Present subsurface structure beneath the Pajarito Plateau to Precambrian crystalline basement is characterized by a Bouger Gravity profile and model. The profile shows a sediment-filled graben 3 km deep beneath the Plateau. It is inferred that faulting associated with this graben and relatively thick sediment accumulations within the graben cause

1) variations in the water table elevations,

2) drawdown to the south and east along the graben,

3) P-wave travel time delays of ∿0.5 sec causing earthquakes epicenters to be mislocated, and

4) unusual positioning of Early Tertiary Galisteo rocks topographically higher then Pleistocene Bandelier Tuff near St. Peters Dome.

Hence, we propose to obtain reversed high-energy seismic reflection profiles along easily accesible roads to carefully delineate near-surface and basement structure which might effect the hydrology and seismology of the Pajarito Plateau.

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Introduction

Present geophysical data on unit distribution and material properties of the volcanic, sedimentary, and crystalline basement consists of a gravity profile from the Sierra de los Valles eastward along the Pajarito Road to the Rio Grande (Keller, 1968).

A structural cross-section from the gravity data suggests that the gently dipping Bandelier Tuff forming the surface of the Pajarito Plateau is underlain by andesites to the west and alluvial sediments of the Santa Fe Group to the east (Keller, 1968). A major graben occurs about 2.5 miles (4 km) east of the Pajarito fault containing 5000 to 9000 feet (0.9-2.17 km) of graben fill and early Tertiary sediments (Figure 1). This graben is 2.3 miles (3.7 km) wide, culminating on the east with a modeled flat basement layer extending to the Rio Grande River. Approximately 6000 feet (1.8 km) of alluvial fill and sediments overlies the basement east of the graben.

Hydrology

The upper surface of the main aquifer rises smoothly westward from the Rio Grande through the Tesuque Formation of the Santa Fe Group into the Puye Formation (Purtymun and Johansen, 1974). Figure 2 shows the regular contouring of the surface of the main aquifer and the stratigraphy and structure of near-surface rocks.

From the structural information in Figure 1, it is clear that although the surface information suggests 500 feet (152 m) of dip slip motion occurred on the Pajarito fault, greater motion has occurred at depth along the fault. This implies that there is an offset of approximately 1000 feet (305 m) between both the andesite units and the top of the crystalline basement on either side of the fault as one progresses down dip in the cross-section. It is suggested that this slip exists because earliest formation of the fault occurred in Pliocene time.

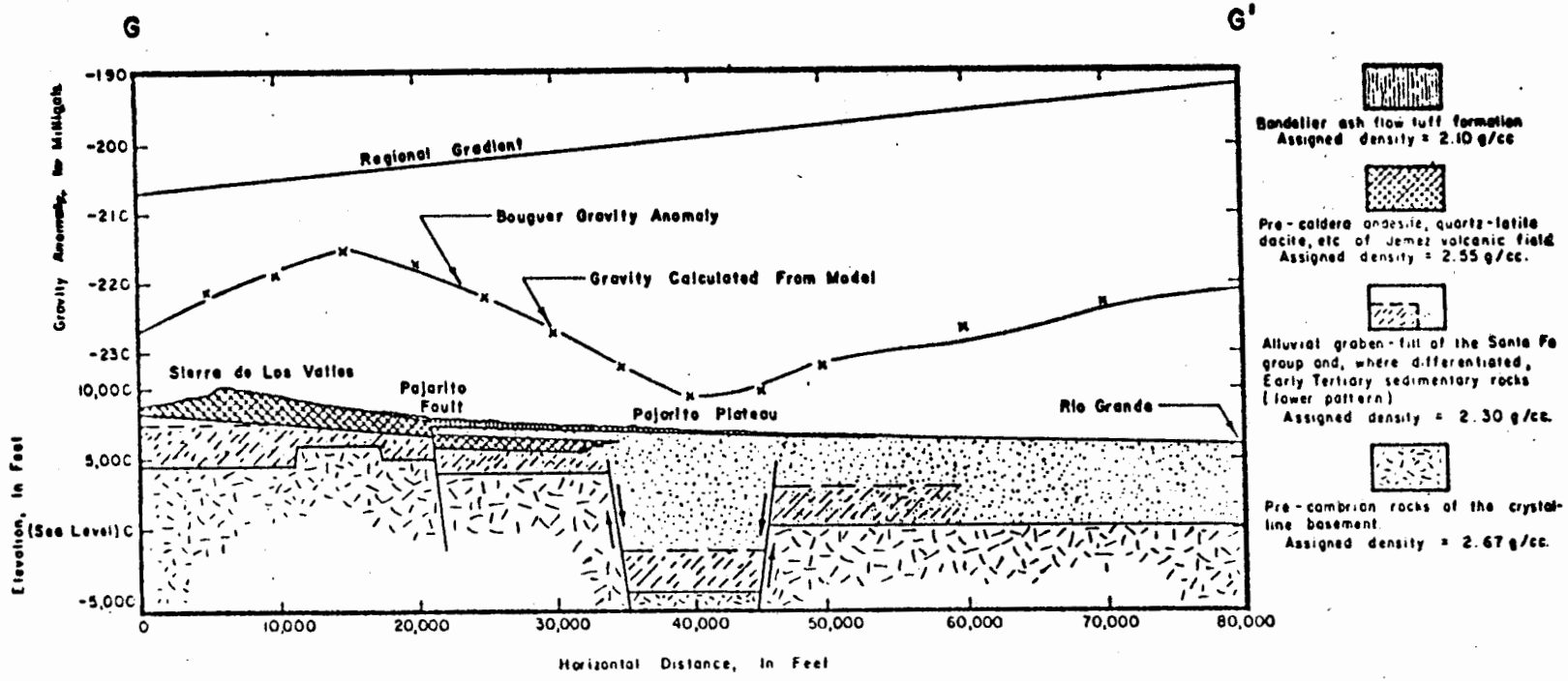

Fig. 2-4. Geologic cross section and gravity profile from the Jemez Mountains to the Rio Grande.
(Section cut on Figure 2-7.)

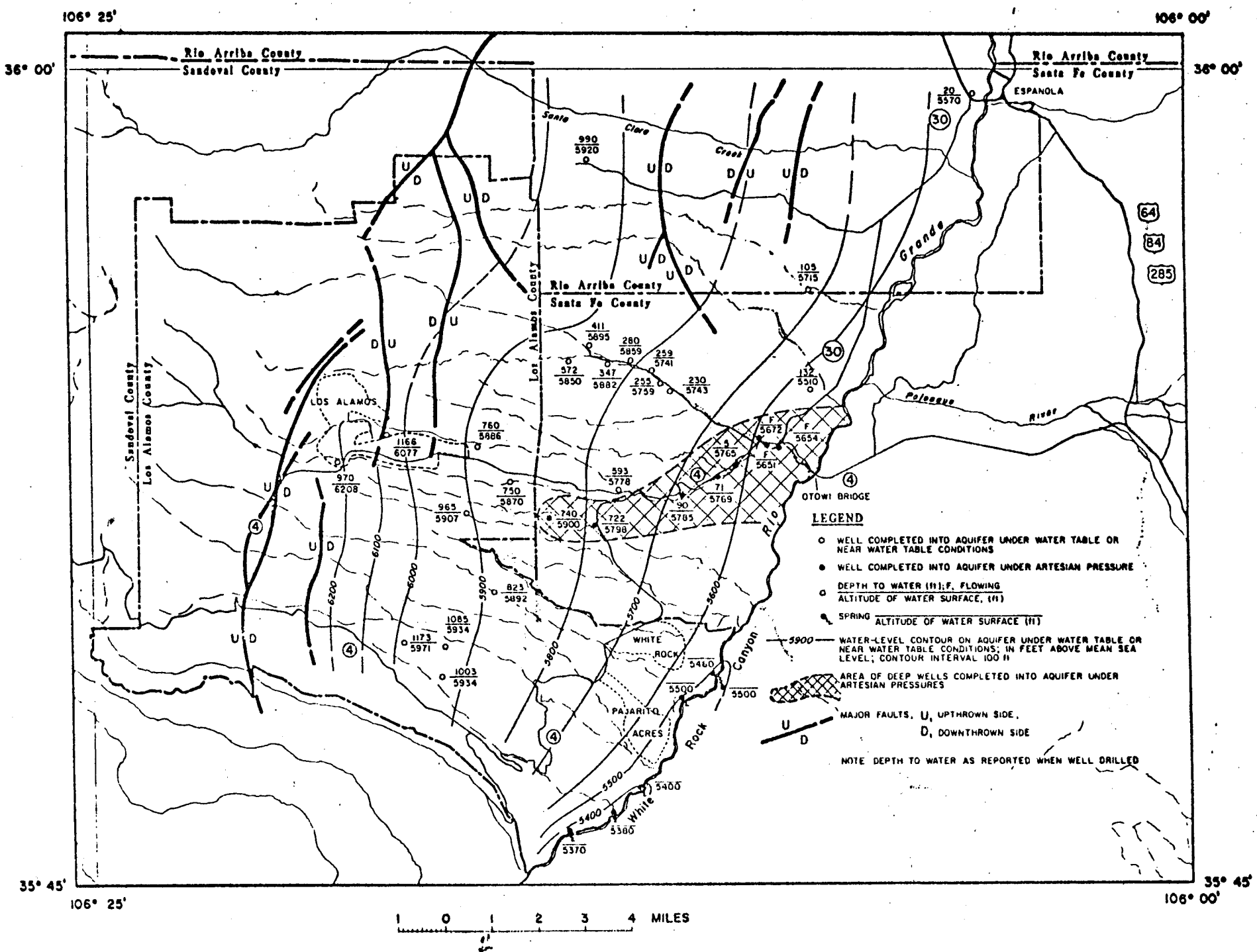

Figure 3. Generalized contours on top of main aquifer.

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Continued motion has caused present Pleistocene surface expression. Hence the 9000 feet (2743 m) of motion on the fault flanking the west side of the graben infers possible motion during the Miocene. It is suggested that this fault motion has been also extended into the overlying alluvial fill of the Santa Fe group.

Purtymun and Johansen (1974) show a structural profile (Figure 3) ranging in elevation from 5000 to 8400 feet extending from Sierra de los Valles to the Rio Grande. The lower elevation of the profile lies just above the inferred graben from the gravity profile (Figure 1). If faulting from this graben is due to a continuing process of structural deformation and extends within 1000 feet of the surface of the Pajarito Plateau, then it should cause the aquifer levels to be modified. Figure 4 is a representation of the effects of faulting on fluid flow suggesting strong modification of the flow around faults.

Ground water moves from levels of higher energy to levels of lower energy, whereby its energy is essentially the result of elevation and pressure. (Davis and de Wiest, 1966). Figure 4a shows streamlines and hypothetical circulation of ground water in a homogeneous isotropic medium with recharge. Note that the water table is analogous to that shown in Figure 3, but clearly the section extends to much greater depths. Geometric construction of a flow net satisfies two conditions; those of boundary and free surface. An impervious surface requires that a potential line be perpendicular. Since streamlines are orthogonal potentials, the impervious surface is a streamline (Davis and de Wiest, 1966). Figure 4b infers the streamline distribution caused by an isotropic homogeneous material whose base is an impervious medium (analogous to the aquifer above the faulted Precambrian basement). While exact position of streamlines is conjectural, if the alluvial fill in the graben is suitable for ground water flow, a potential sink exists in the graben. Clearly the streamline dips into the graben and if no energy is supplied, ground water would not move up the streamline out of the graben. Rather, it would tend to move along the graben. Hence the graben

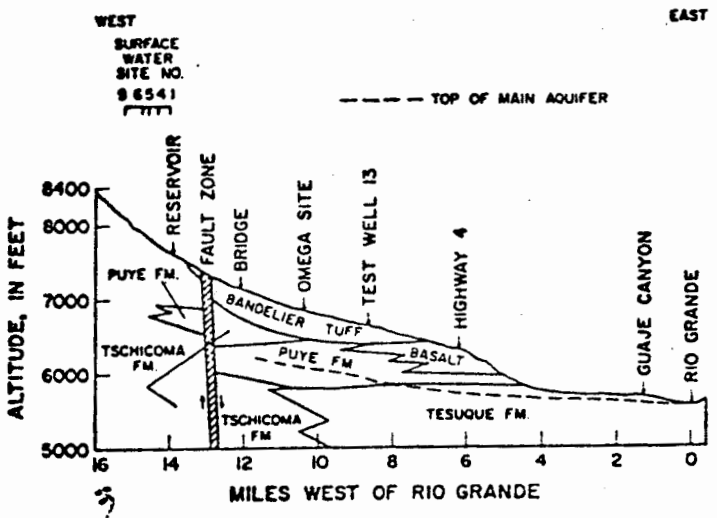

Figure 2. East-west geologic section through the Pajarito Plateau.

from Purtymun and Johnson

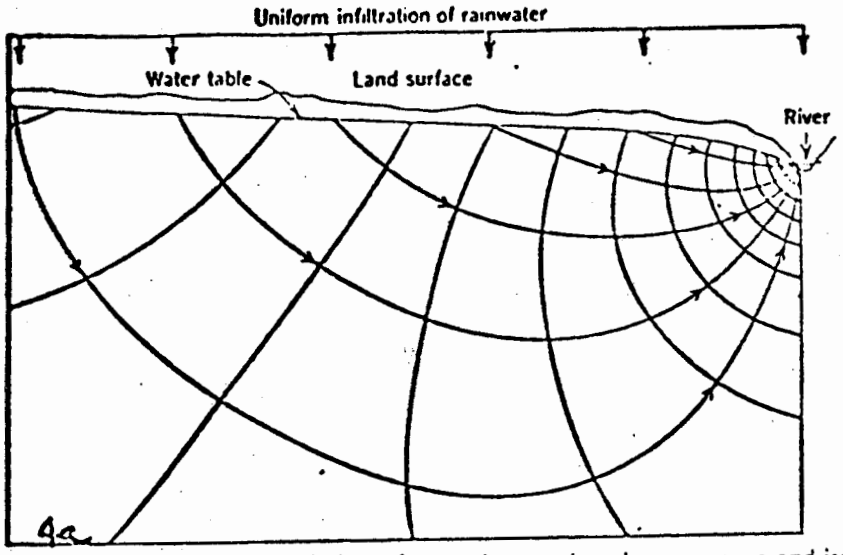

Figure ~~10.11~~ Hypothetical circulation of ground water in a homogeneous and isotropic medium with recharge. (from Davis and De Wiest, 1966)

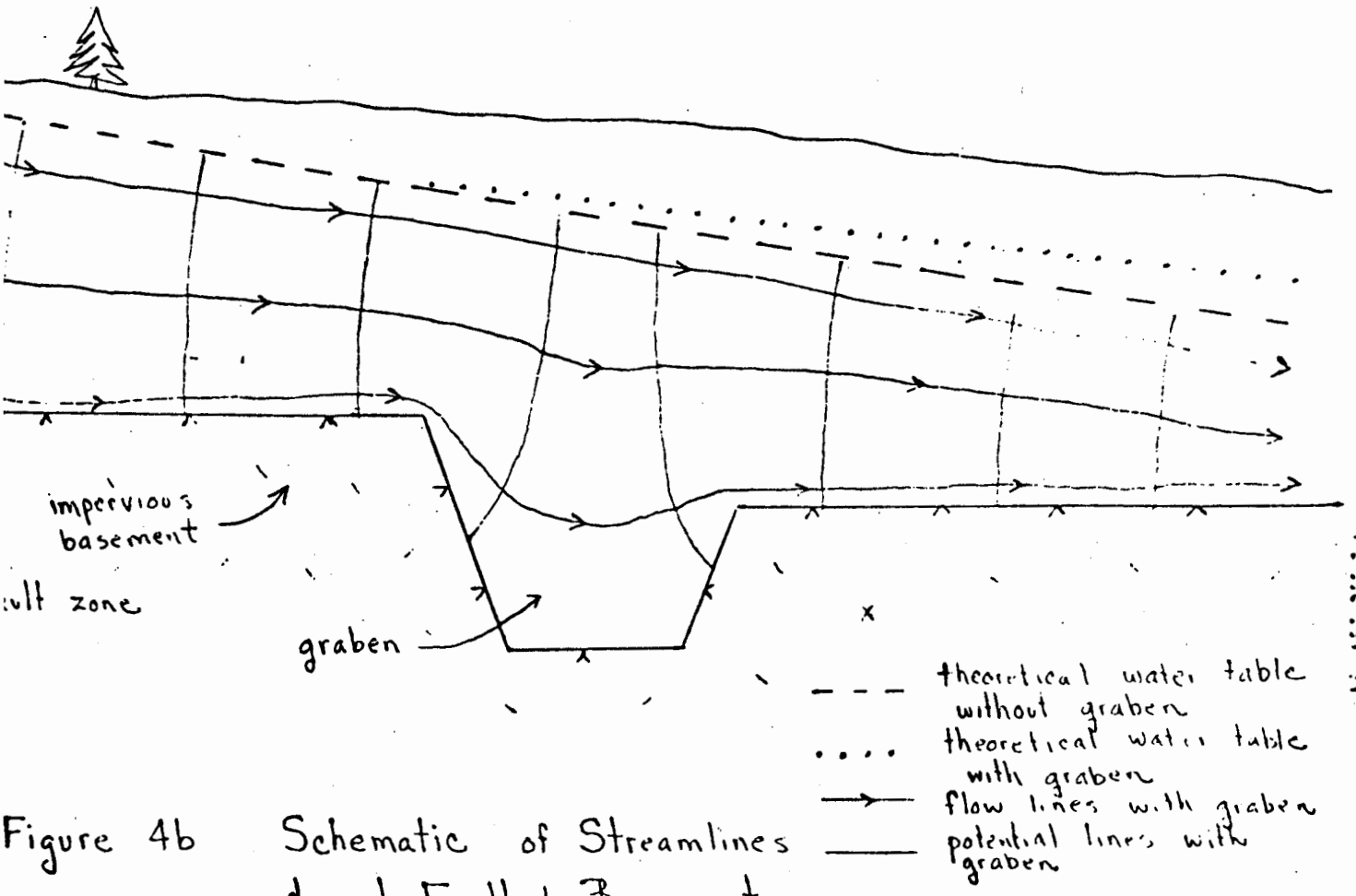

Figure 4b Schematic of Streamlines due to Faulted Basement

could provide drawdown of the water supply of the Pajarito Plateau toward the south and east, significantly altering the geohydrology of the Pajarito Plateau.

Clearly, careful delineation of the extent of faulting beneath the Pajarito Plateau to the top of the crystalline basement would show possible effects of the spatial distribution of Santa Fe sediments (the aquifer) and potential drawdown to the south.

Seismology

Two seismic instruments, one a vertical component and the other a 3 component system are in operation on the Pajarito Plateau by Group J-9, LASL. The former is located at Frijoles Canyon (FCN) south of TA-33 and the latter is located at TA-49 (LOA). All seismometers have natural resonant periods of 1 Hertz and are especially suitable for detecting local and regional microearthquakes with dominant frequencies in excess of 3 to 5 Hertz. Typical magnification of records ranges from 50,000 to 100,000 at 1 Hertz. Present P-wave travel time delays indicate 0.5 sec at LOA and 0.3 sec at FCN relative to seismometers at Clara Peak and St. Peters Dome. The latter are on relatively competent basalts and andesites. Landers (1974) has numerically modeled emergent plane P-waves transmitted through a graben and finds the wavefront above the graben to be high in amplitude and time-delayed above the graben. The LOA and FCN delays are interpreted as being caused by the southern extension of this graben (shown in figure 1 south) the. Hence present simplified 2 layer velocity model results in errors for location of earthquake epicenters. Detailed velocity profiles would provide proper velocity models and delay times required to accurately locate earthquake epicenters.

Geology

Geology of the west-flank fault of the graben consists of Santa Fe alluvial fill overlying Early Tertiary rocks which are nonconformable on Precambrian crystalline basement (Figure 1). The Precambrian top presently exists at an elevation of 4000' (1200 m). Just east of St. Peters Dome, Smith and others (1970)

show a remnant of Early Tertiary Galisteo Formation on the upthrown block of a normal fault. ~~which is downthrown to the east.~~ Reconnaissance geology indicates that this Galisteo(?) remnant is at a higher elevation than the underlying Bandelier Tuff and is overlain by Pliocene Paliza Canyon andesites. If the Early Tertiary sediments of the graben (Figure 1) are correlative with the Galisteo, then this fault could represent the western fault flanking the graben. Hence, it is inferred that seismic delays are caused by unusually thick alluvial graben fill and the graben might have a regional trend shown in Figure 5. Clearly, a seismic reflection profile along State Highway 4 would confirm this hypothesis.

Access and Location of Seismic Reflection Profiles

Access to the Pajarito Plateau for seismic reflection profiling is conveniently located both along the Pajarito Road and along State Highway 4 near Bandelier Monument (Figure 5). Each of these roads is between 8 and 10 miles in length, essentially traveling down true dip of the Bandelier Tuff. Inferred station spacings of 1/2 mile could be used for regions where simple structure occurs although it is recommended that station density be increased in the vicinity of the known graben to perhaps 1/4 mile spacing. Since there is evidence of a graben trending approximately north-south beneath the Pajarito Road it seems essential to provide a profile along State Highway 4 to clearly define the trend of this subsurface structural feature. To correctly specify the regional dip of various units it is recommended that reversed reflection profiles be used.

As is noted from Figure 1, a variety of material properties is inferred from the sedimentary units of the structural section. A density inversion occurs beneath the andesites of the western area. In addition, it is expected that increased attentuation of seismic energy can be expected due to the low density and porosity of the Bandelier Tuff. Hence it is recommended that high energy sources be used for the reflection profile.

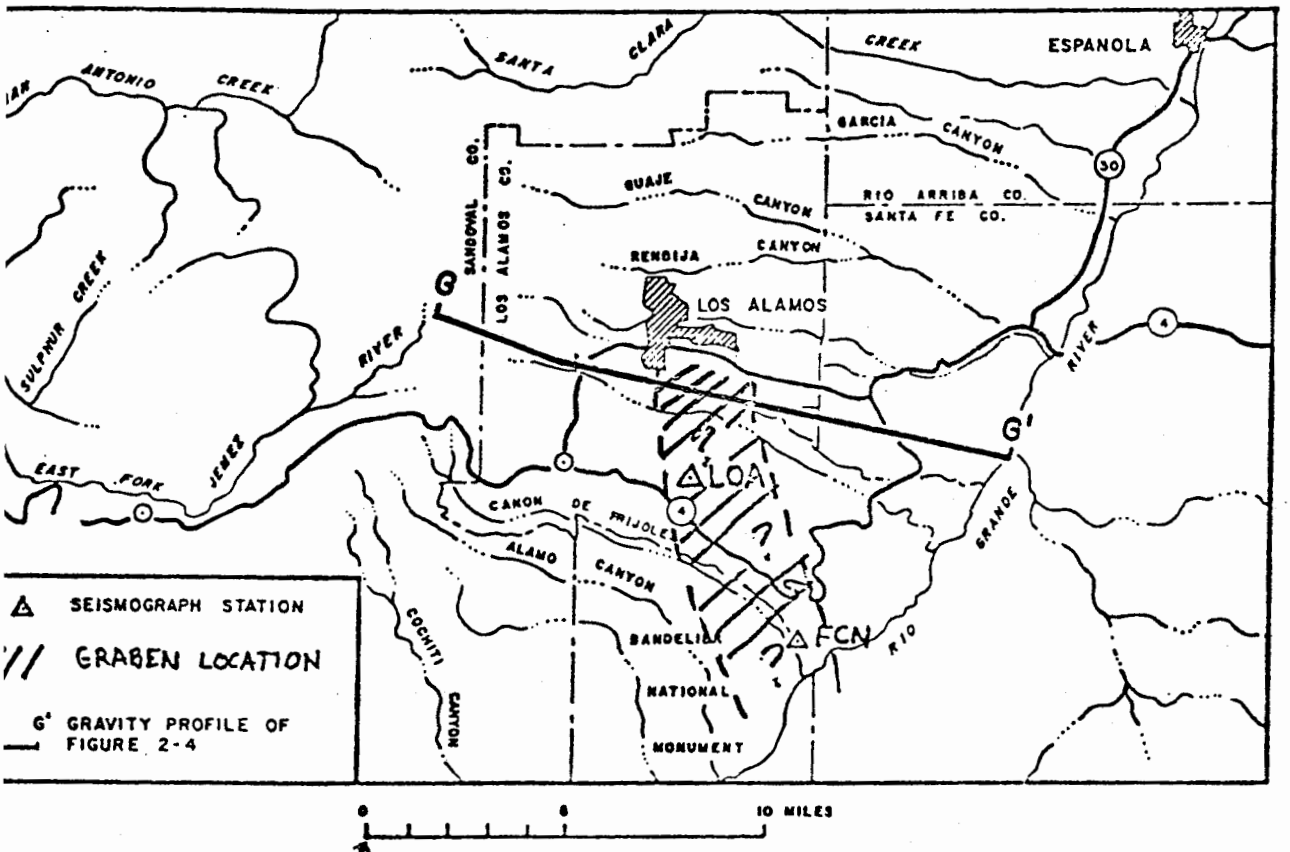

Fig. ~~2-4~~ 4. Seismograph stations and sample localities.

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Proposal

Fundamental geophysical control of subsurface structure affecting geohydrology and seismology consists of a calculated gravity model of the Pajarito Plateau. This model is a best fit for assumed densities (Cordell, Personal communication, 1974) and there may be significant variation of thickness and lateral continuity depending on these assumptions. This structural model affects geohydraulic potential by suggesting a substantial increase in aquifer thickness and a potential drawdown to the south. Evidence that the graben extends southward is suggested by P-wave travel time delays at LASL's seismic stations. Regional relations of geologic structure strongly support a postulated trend of the graben south beyond St. Peters Dome.

We propose to obtain reversed high-energy seismic reflection profiles to carefully delineate structure to the Precambrian basement. Each profile should be approximately 8 to 10 miles long beside easily accessed paved roads. Between 20-26 stations per profile would be required to provide the lateral and vertical variation in seismic velocities inferred from the gravity profile. Two profiles are required; the northern one along Pajarito Road to confirm gravity data and the southern one along State Highway 4 to delineate the trend and depth of the graben toward St. Peters Dome.