Basalts of the Mid-Tertiary Thirtyone Mile Volcanic Center, Central Colorado

Andrew Tittler, Williams College Geology Department

Introduction The Thirtyone Mile volcanic center is located within the Thirtynine Mile volcanic field in mid-Colorado. It lies just southwest of the main eruptive center at Guffey, and had been tentatively dated on the basis of field relations as somewhat older than Guffey. Structurally, it is separated from the Guffey center by the Currant Creek Fault zone, one of the major planes of weakness in the state. Like the rest of the Thirtynine Mile volcanics, it consists of a main body of andesite, with small amounts of basalt and rhyolitic material at either end of the chemical spectrum. The andesite at Thirtyone Mile Mountain forms a central dome and many smaller flows. The rhyolitic material is present largely as pyroclastics, with an occasional dike, generally beneath or on the periphery of the main dome. The basalts occur as flows, sills and dikes throughout the volcanic column. This paper deals with the basalts, in an attempt to shed some light on the deep sources of the volcanism, as well as on the timing and evolution of the magmas through time.

Field observations

The field area studied consisted of the north side of Thirtyone Mile Mountain, with sites on the east and west flanks, concentrating on the area northwest of the peak as far as Baldy Mountain. The basalts in this area fall into two structural patterns: the first a number of dikes extending throughout the area, the other a series of sills and/or flows. The dikes range from under a meter to over two kilometers in length, and from a centimeter to about four meters in width. Horizontal occurrences of basalt up to five meters or so in thickness cover a surficial area of up to several hundred square meters, though exposures were generally smaller than this. It was usually impossible to tell whether these occurrences are in fact sills or flows; in only a few cases were vesicles and other structures found that conclusively confirm the presence of a surface flow.

The basalts can further be subdivided into porphyritic and non-porphyritic types: phenocrysts of pyroxene in some specimens are up to 8mm in length. With only one exception, all the horizontal bodies of basalt are porphyritic, no matter where in the stratigraphic column they lie. The equigranular basalts, on the other hand, tend to form clean, massive dikes, with jointing occasionally visible. The non-porphyritic rocks are by far the minority, and do not form the majority even of dikes. In one place, a non-porphyritic sill cuts a porphyritic dike, giving credence to the idea that the equigranular rocks consituted a later episode, particularly since they appear much more often in the upper reaches of the stratigraphic column. All the confirmed flows are near or at the bottom of the volcanic pile, as are nearly all the sill-like structures. Higher up, all that is found are dikes, of both equigranular and porphyritic types.

Petrographic Data

Petrographic analysis of twenty-nine samples of these basalts shows an almost universal composition of intermediate plagioclase, clinopyroxene, olivine, and opaques, with several minor minerals, mostly alteration products (hematite, iddingsite, chlorite) Neither amphiboles nor orthopyroxenes were seen. Most of the samples are porphyritic: clinopyroxene is always a phenocryst phase, as well as being found in the groundmass. All three other major minerals occur as phenocrysts, though much smaller ones. The large pyroxenes visible in hand specimen are almost all glomeroporphyritic clusters, often containing magnetite and even olivine and plagioclase. Clinopyroxene is a major mineral even in those samples in which it is not a significant phenocryst component. Modally, plagioclase forms about 50% of an average sample, sometimes more, rarely less, with Cpx about 20% and olivine and magnetite making up the remainder. Magnetite is always present, evenly distributed throughout the groundmass and phenocrysts, and even forming small phenocrysts of its own. It is altered to hematite in a few samples, but is usually intact. Olivine, by contrast, is sporadically present as phenocrysts, but always present in the groundmass, though usually almost completely altered. Plagioclase is always distinguishable, but sometimes is weathered enough to make looking at groundmass texture difficult. Cpx was easiest of all to distinguish, being usually pristine, and often froming euhedral crystals with well-defined cleavage.

Textures range from massive to trachytic, with the best lineation developed by the plagioclase laths forming the groundmass in samples taken from some of the dikes. Those taken from flows had some alignment, but not nearly as much.

Chemical Data

Eleven samples were analysed for both major and trace elements using both XRF and ICP, and five were also analysed for trace elements by INAA. What was remarkable about the samples was not their minor differences, but their similarities, even between rocks of massive and porphyritic types.

An R1/R2 plot (fig 1) puts these rocks into the sub-alkaline suite. Not surprisingly, they all contain between 48 and 52% silica, with total alkalies 6-8%, about half of that Na, half K. A total alkalies - silica plot shows that most of these samples fall into the general category of trachybasalt, with some in the field of shoshonites.(fig 2, from Wobus et al, 1990) AFM and K-Na-Ca plots (figs 3 and 4)show rocks of remarkably similar composition, all in the alkali basalt range. Si, Al, and Ti values place them well within Manson's characterisation of continental basalts, (Manson, 1967) Si and Al being higher than the oceanic average, and Ti values being lower.

Trace element analyses show high Ba, Sr, and Rb; Ba ranges from about 1400ppm to about 2500ppm and Sr averages about 1000ppm. Compared to average basalt values (Prinz, 1967), all these are very high, and the more compatible elements Co, Ni, and Cr are all low, indicating a fair degree of fractionation and/or contamination. A spider diagram (fig 5) show enrichments of up to 800 times, averaging to about 100 times average chondritic values. These are compatible with results from elsewhere in the Thirtynine Mile field. (Goldman et al, 1989)As elsewhere, REE plots (fig 6) show decreasing concentrations from light to heavy rare earths, with no europium anomaly.

Conclusions

Since all the samples have very similar modal compositions and chemical signatures, it would seem that they all originated in the same magma chamber. Perhaps the earlier, porphyritic magmas merely rose and cooled more slowly, allowing phenocrysts more time to form, while the later magmas rose more swiftly, and solidified without having had a long enough period to form or accumulate large phenocrysts. However, one still has to account for the fact that these basalts were being emplaced more or less at the same time as the andesites that comprise the bulk of the center. The basalts would seem to point to a common deep source area, from which pulses of magma rose, melting and ingesting crustal rock to the point where most of the pulse became andesite, and only a small portion, perhaps near the bottom, retained its original character. From the field data it is apparent that at least two pulses of magma were involved; one early, preceding and along with the early andesites, and another late, after the bulk of the volcanism.

The data for this area fits in well within the larger context of the Thirtynine Mile field. Chemical data fits well with work done on basalts of the Guffey center, although the Thirtyone Mile basalts do show a simpler modal makeup, laking the hornblende annd orthopyroxene seen in some of the more shoshonitic rocks from Guffey (Eide, 1987) The alkalies - silica plots and the REE plots tally all but perfectly with the Guffey data. (Wobus et al. 1990)There can be no question that the two episodes are intimitely related, and shared the same ultimate magma source

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Figure 1

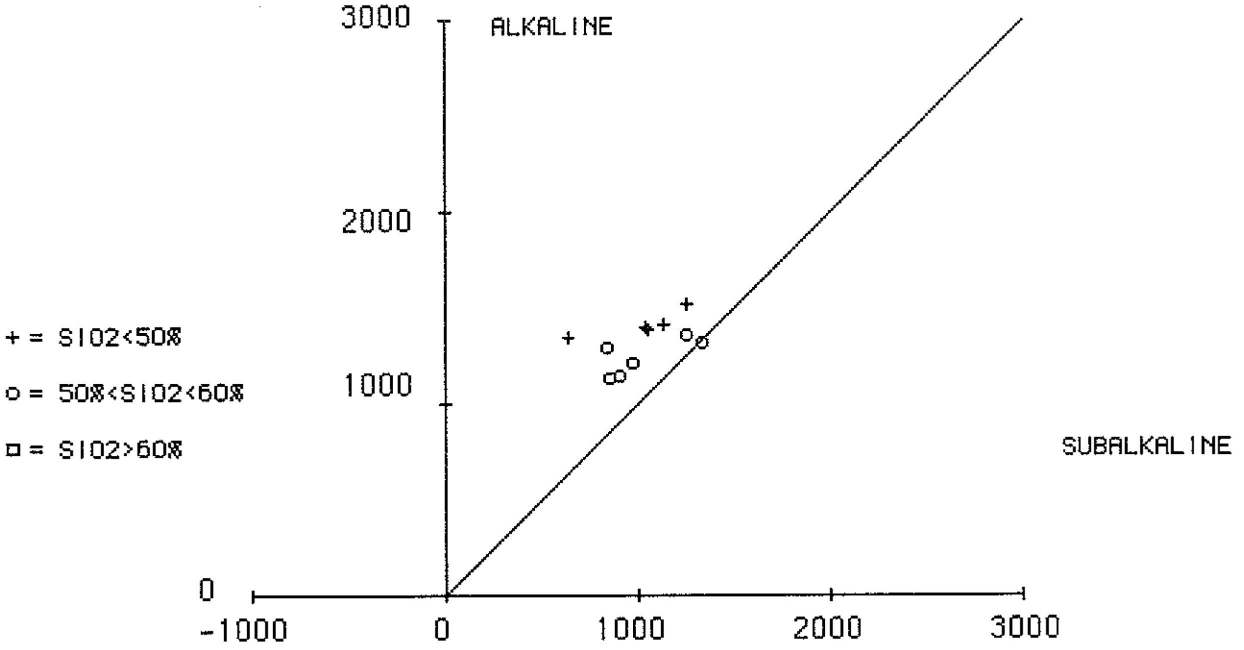


Figure 2: Alkalies vs silica

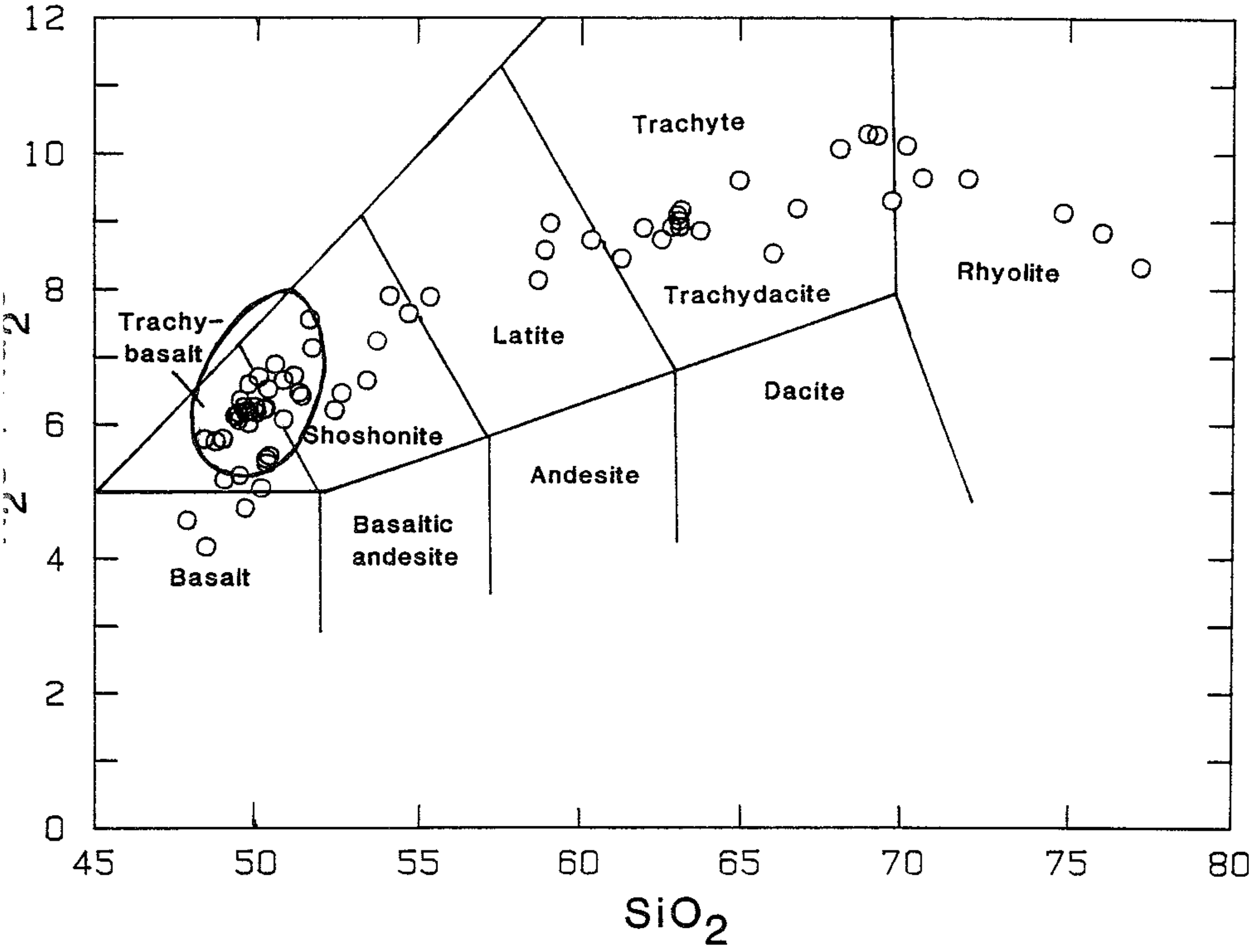


Figure 3

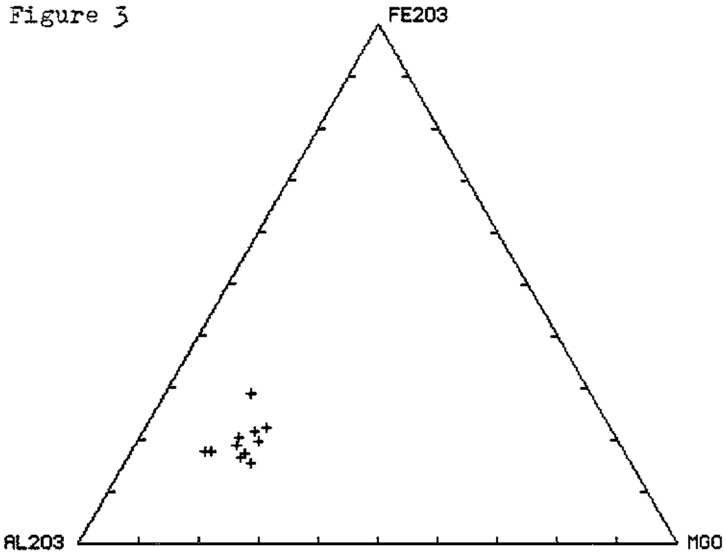


Figure 4:

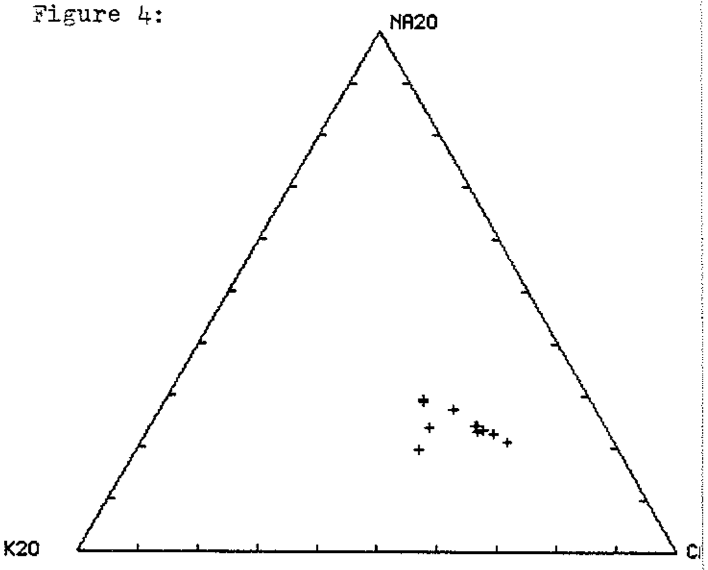
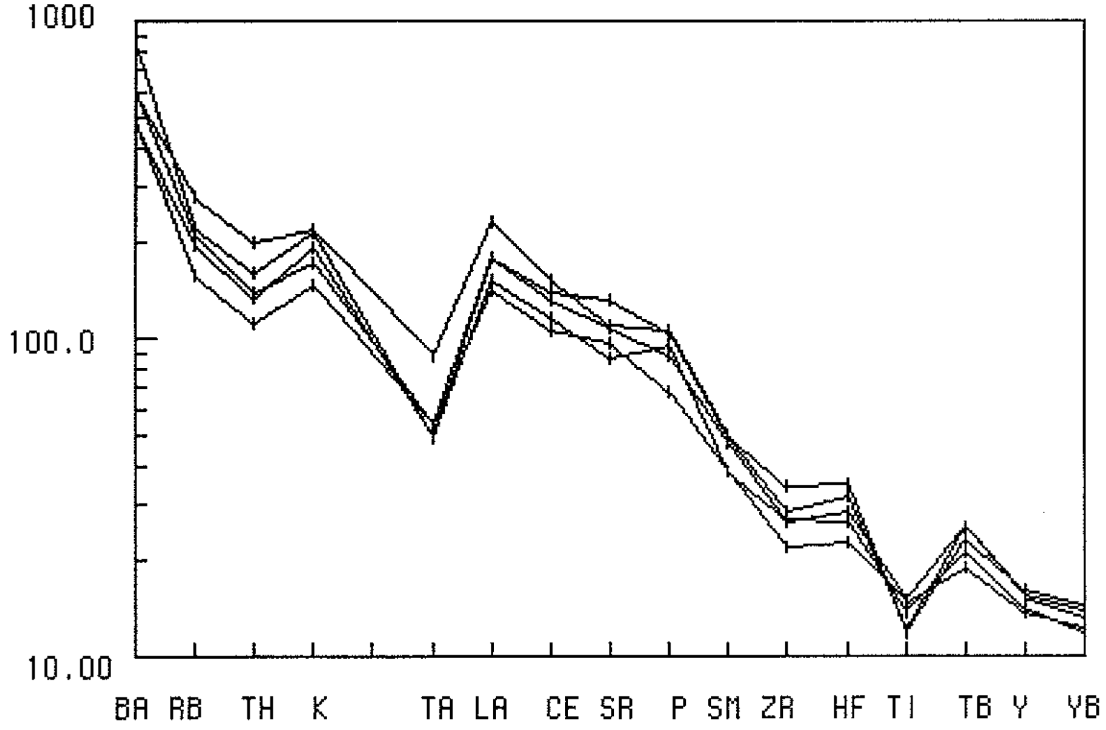
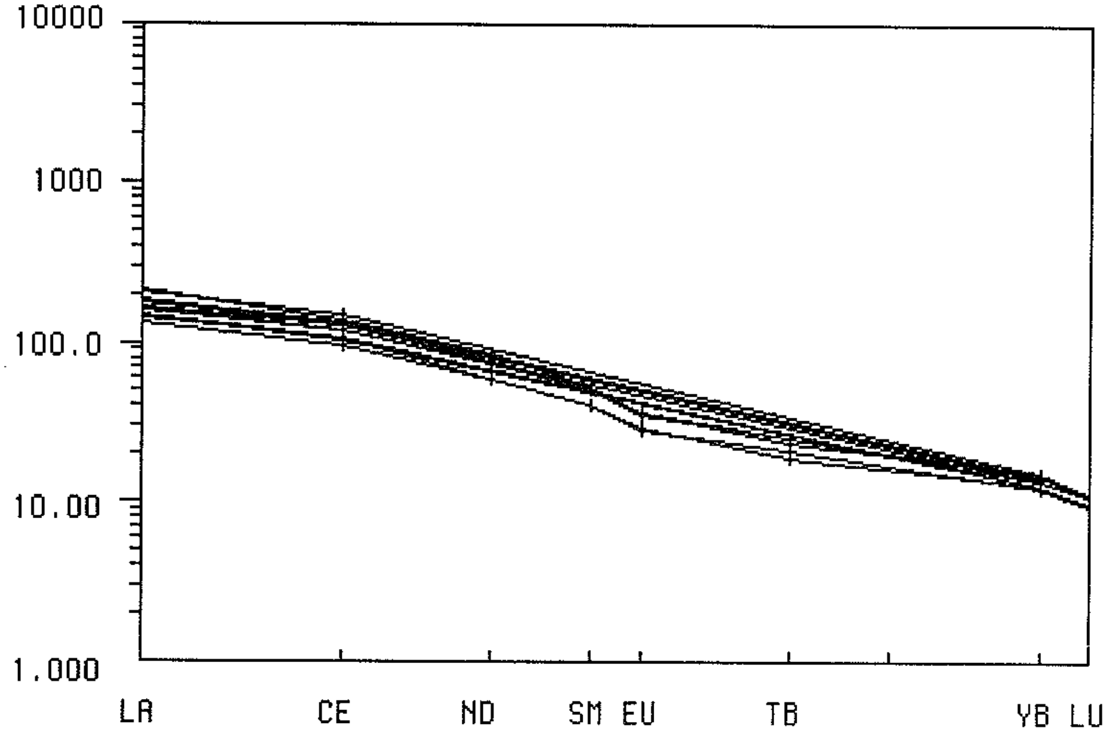


Figure 5



igure 6: REE plot



GRAVITY SURVEY OF THE GUFFEY VOLCANIC CENTER, THIRTYNINE MILE VOLCANIC FIELD, PARK COUNTY, COLORADO

Gregory A. Wimpey and Mark Andrew Tinker
Department of Geology
Trinity University
San Antonio, TX 78212

Introduction

The Oligocene Thirtynine Mile volcanic field is the second largest volcanic field in the southern Rocky Mountain region, covering over 2000 km^2. The Guffey volcanic center, the largest center within the Thirtynine Mile field, is expressed as an elliptical topographic feature approximately 15 km in length along its east-west axis and 8 km in length along its north-south axis. Thirtynine Mile, Saddle, Castle, Witcher and Cover Mountains, exhibiting from 1000 - 2000 feet of relief, form the perimeter of this elliptical structure. These hills, composed of stratified volcanics that exhibit quaquaversal dips, are composed predominantly of mafic to intermediate flows and lahar deposits. Within the structure, numerous plugs, dikes, and vents cut these thick mafic deposits.

There are several possible origins of the elliptical topographic expression of the Guffey volcanic center. A single, large, volcanic edifice may have produced a subsidence caldera. Alternatively, the feature may be an erosional caldera (Williams, 1941). It is also possible that no large edifice existed and that the elliptical topography is the result of active imaginations. Collapse calderas are clearly reflected in the observed gravity in the nearby San Juan volcanic field (Plouff and Pakiser, 1972). In the summer of 1990 we conducted a local gravity survey of the Guffey volcanic center in order to determine if a subsidence caldera is evidenced by the local gravity field.

Field Methods

Surveying

A gravity meter measures the difference in gravity between locations to a precision of one hundredth of a milliGal (mGal), or one part in one hundred million of the acceleration of gravity. If present, the gravity anomaly caused by a caldera structure might be as small as several milliGals. At the latitude of Guffey, a 400 ft change in latitude would result in a gravity change of approximately 0.1 mGal. An elevation change of one foot would produce a gravity change of approximately 0.06 mGal. Thus, elevations and locations taken from topographic maps would not allow us to achieve an overall accuracy of better than 0.1 mGal, and it was necessary to survey each gravity station. We employed a Lietz SET4 Total Station with an SDR electronic data collector. This system measures distances with an infrared beam reflected from a target prism. Horizontal and vertical angles are measured electromechanically to a precision of 5" of arc. The data was reduced using the data collector's topography program, which calculated and recorded station locations by easting, northing, and elevation with a precision of 0.001 ft. At the conclusion of each day, the data was downloaded from the electronic data collector into a Macintosh IICX.

The theodolite was set up at a base station, from which subsequent stations were shot at approximately 600 foot intervals. The maximum distance we shot from a base station was approximately 3000 feet; however, shots were usually limited to much shorter distances because of terrain obstruction. New base stations were established at previously surveyed stations, and back shots were performed to reestablish the azimuthal orientation of the theodolite. Each station was flagged and given a station number. Once a station was established, it could be reoccupied for gravity measurements whenever necessary (unless the flag was removed by animals or cranky ranchers).

Station locations

One hundred and fifty eight stations were established in locations which would provide profiles crossing the margins of the elliptical topographic feature as well as good radial coverage of the northwestern quadrant of the feature. Station locations were chosen in as flat an area as possible in order to minimize terrain effects.

Benchmarks G290 and H290 along West Fourmile Creek were surveyed and defined a baseline for all subsequent surveying. Sixty-four stations were established along West Fourmile Creek, extending approximately 6.5 miles east from its intersection with Thirtynine Mile road. This set of stations extended across the eastern margin of the elliptical structure. Fifty stations were located along Thirtynine Mile Road, extending approximately 5 miles north from West Fourmile Creek crossing the northern margin of the elliptical feature. Two additional lines