RESEARCH PROPOSAL SUBMITTED TO

THE UNITED STATES GEOLOGICAL SURVEY

TITLE: Crustal Seismic - Refraction Investigations of the Geothermal Potential in the Central Rocky Mountains.

SUBMITTER: MicroGeophysics Corporation
607 Tenth Street
Golden, Colorado 80401
(303) 279-0226

PROPOSED AMOUNT: $65,441

PROPOSED DURATION: 1 year

PROPOSED STARTING DATE: 1st of May, 1977

PREPARATION DATE: January, 1977

B. TABLE OF CONTENTS

C. Abstract

A program of crustal-scale seismic-refraction studies in the Southern Rocky Mountains is proposed. The refraction lines are located between Hayden and Climax, Colorado and between Climax, Colorado and Questa, New Mexico. The lines cross features of geothermal interest including the Dotsero Plume, the Mt. Princeton area, the northern San Luis Valley and the Rio Grande Rift. Features of the work include the use of very energetic industrial blasts as sources, continuously recording digital-tape recorders, an array of stations to detect out-of-line propagating energy, and a new method of calculation for the interpretation of the records.

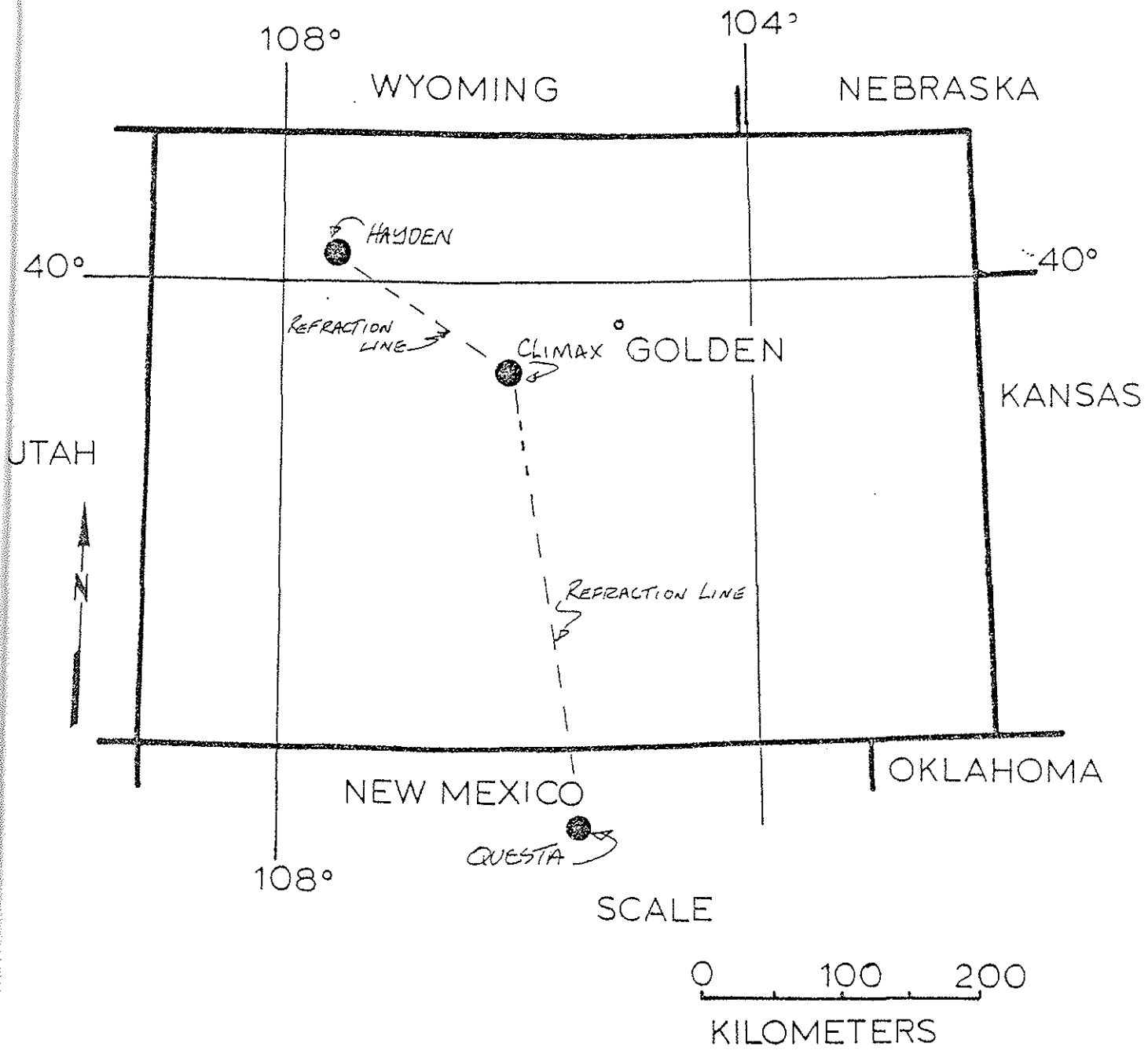
Significant results expected are details of velocity distributions within the Colorado Plateau province, structural details near the most promising geothermal prospects in Colorado, and information about the seismic expression of the northern end of the Rio Grande Rift. The depths extent of the Dotsero Plume, manifested by some of the youngest volcanics in Colorado (less than 4,000 years old), will be evaluated as a potential source of geothermal energy. The Rio Grande Rift is the site of one potentially commercial geothermal field at the Jemez Caldera. The rift is a locus for additional exploration even though the seismic nature of its structure at depth is poorly known. This work will add substantially to

knowledge about a continental rift, a potential plume, and the relationship of these features to geothermal energy.

D. Introduction

Seismic-refraction investigation of the crustal structure of the Central Rocky Mountains is proposed. Geothermal interest in Colorado has centered on three areas: the Mt. Princeton area in the Upper Arkansas Valley, the northern San Luis Valley, and the Dotsero Plume. A unique opportunity exists to obtain reversed refraction profiles across these geothermal features at modest cost. Mining shots of sufficient strength to be recorded at distances adequate for crustal investigation are a documented part of the seismic regime in the Central Rockies. Sufficient equipment is available to use arrays of detectors augmented by some three-component sites. Computer-compatible continuous digital recording will improve the effectiveness of the field work. The lines proposed, from Hayden to Climax, Colorado, and from Climax to Questa, New Mexico, also cross a significant portion of northern extension of the Rio Grande Rift, a puzzling, midcontinent, global-scale feature. (See Figure 1).

The interpretation method involves the calculation of synthetic seismograms by the method of kinematic discontinuities by the Yang-Hadsell method. Any deep-seated anomalies due to the geothermal occurrences will be documented.



TITLE: LOCATION MAP		
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E. Technical Discussion

The seismic refraction method has been used for crustal-scale investigations by many (Smith, Braille, Meyer, Pakieser and others). Most significant has been the work on the Wasatch Front area of Utah. This work, on the boundary between the Colorado Plateau and the Basin and Range Provinces, has yielded a significant appreciation of the seismic difference between these two crustal megastructures. The present study will investigate the seismic underpinnings of two such structures: the "monolithic" Colorado Plateau and its structural interaction with the Rio Grande Rift. Though the results are not known, previous investigations (Crompton, 1976) indicate the following interesting anomalies:

1. Significant crustal p-wave delays in the vicinity of the geothermal occurrences.
2. A probable horizontal refraction at the boundaries of the Rio Grande Rift.
3. Significant absorptive properties of the crust within the rift.

This previous work indicated the necessity for recording refraction profiles by an array of instruments rather than by the use of the assumption of in-line propagation of refraction energy.

The geothermal area at Mt. Princeton is possibly at the

boundary of the Rio Grande Rift. Its regional structural setting, investigated by Crompton, should be investigated in more detail. The Northern San Luis Valley is an area of active investigation by the Colorado Board of Water Resources. The results of this study will indicate the deep crustal structure beneath geothermal prospects in the San Luis Valley. In fact, coordination and cooperation with the ongoing investigation by the Colorado Board of Water Resources will be the responsibility of the coprincipal investigator (GVK).

The Dotsero Plume is an outpouring of very recent volcanics dated to be less than 4000 years old. The volcanics are geographically related to hot spring occurrences at Dotsero, Hot Sulphur Springs and Glenwood Springs. The depth, extent, structural nature, and significance of these volcanics in a geothermal sense is unknown at present.

Several new sources of seismic energy are available in Central Colorado. Several of the new coal strip mines in Routt County shoot 20-25 thousand pounds of explosives every day or two. The signals are easily observed at distances of 200 km. The new molybdenum mine at Henderson in the Front Range will have some large shots as will the Questa Mine of Molycorp of America just across the state line in New Mexico. The Climax molybdenum mine near Leadville, Colorado, is centrally located and is a reliable provider of recordable seismic energy out to distances of 200 km. The length of the

proposed refraction lines are Hayden-Climax 155 km and Climax-Questa 285 km. The Hayden-Climax profile will have abundant sources and energy. Previous work indicates that seismographs on the opposite side of the Rio Grande Rift from the events will receive severely attenuated energy.

Because this attenuation of the rift is one aspect of this study, the evidence for the attenuation will be reviewed. Crompton (1976) at 200 km from modest shots at Questa found that the seismograms recorded in the Upper Arkansas Valley were vanishingly small. The ray paths would cross the Rio Grande Rift. Simon (1969) reviewed the seismicity of Colorado and found that in 12 years of recording at GOL (near Bergen Park, Colorado) no events were detected at or near the Mt. Princeton area. However, an interim statewide network operated by NOAA for six months recorded and located at least two events from this area. There are two possible explanations-severe temporal non-stationarity or severe attenuation on the GOL-Mt. Princeton path. GOL experiences unusal attenuation for Southern California events (the GOL magnitude for the San Fernando earthquake was 5.3) but, of course, the attenuation could occur anywhere along the ray path.

One feature which will reduce the cost of this work is the type of equipment to be used. The seismographs run continuously, thus removing the necessity for radio communications with the shot point.

The equipment consists of an LC-4 Mark Products, 1 Hz natural-frequency seismometer, a MEQ-800B amplifier and smoked paper recorder with integral crystal clock timing, a computer-compatible 12-bit, 100 samples per second digital magnetic tape recorder with integral WWVB receiver. The signal is recorded simultaneously on the smoked paper and the digital tape. Time signals from the crystal clock are recorded on the smoked paper and on the tape; WWVB time signals are recorded continuously on the magnetic tape. The tape is recorded at 800 bpi and a 2450 foot roll of tape will run more than 25 hours. Eleven such tape units are available. In addition, 5 MEQ 800B-s with smoked paper-only recordings are available.

In fact, the 16 components of recording mentioned above are scarecly enough to do this job properly. Previous work is based on the assumption that the seismic energy is propagated along a straight line from the source to the detectors. This in line propagation assumption, openly stated by careful investigators, is violated in complicated structural features such as the Central Rockies (Crompton, 1976). Thus, this investigation will use arrays of detectors, and the apparent direction of propagation will be an important finding of this survey.

The "wavefront sample" thus obtained could be interpreted with a three-dimensional model. Because such models are not readily available, interpretation will be based on more conventional models and some simplifying assumptions. This

type of interpretation almost always leads to nonunique models but if several such models are considered, and the favored interpretation is consistent with ancilliary information such as geology, the process of interpretation is reasonable, viable, and believable.

The ability of the Yang-Hadsell approach to calculate all of the seismic arrivals (refracted, reflected, wide-angle reflections, etc.) at any point in a layered earth will be used to prepare synthetics for comparison with the data. This calculation method based on the method of kinematic discontinuities of Cagnaird, correctly calculates both amplitude and wave shape for the model input. The models so prepared will be reconciled with the well-known surface geology of this area. A quantum increase in knowledge about the physical setting of the most interesting geothermal areas of Colorado is anticipated.

LIST OF REFERENCES

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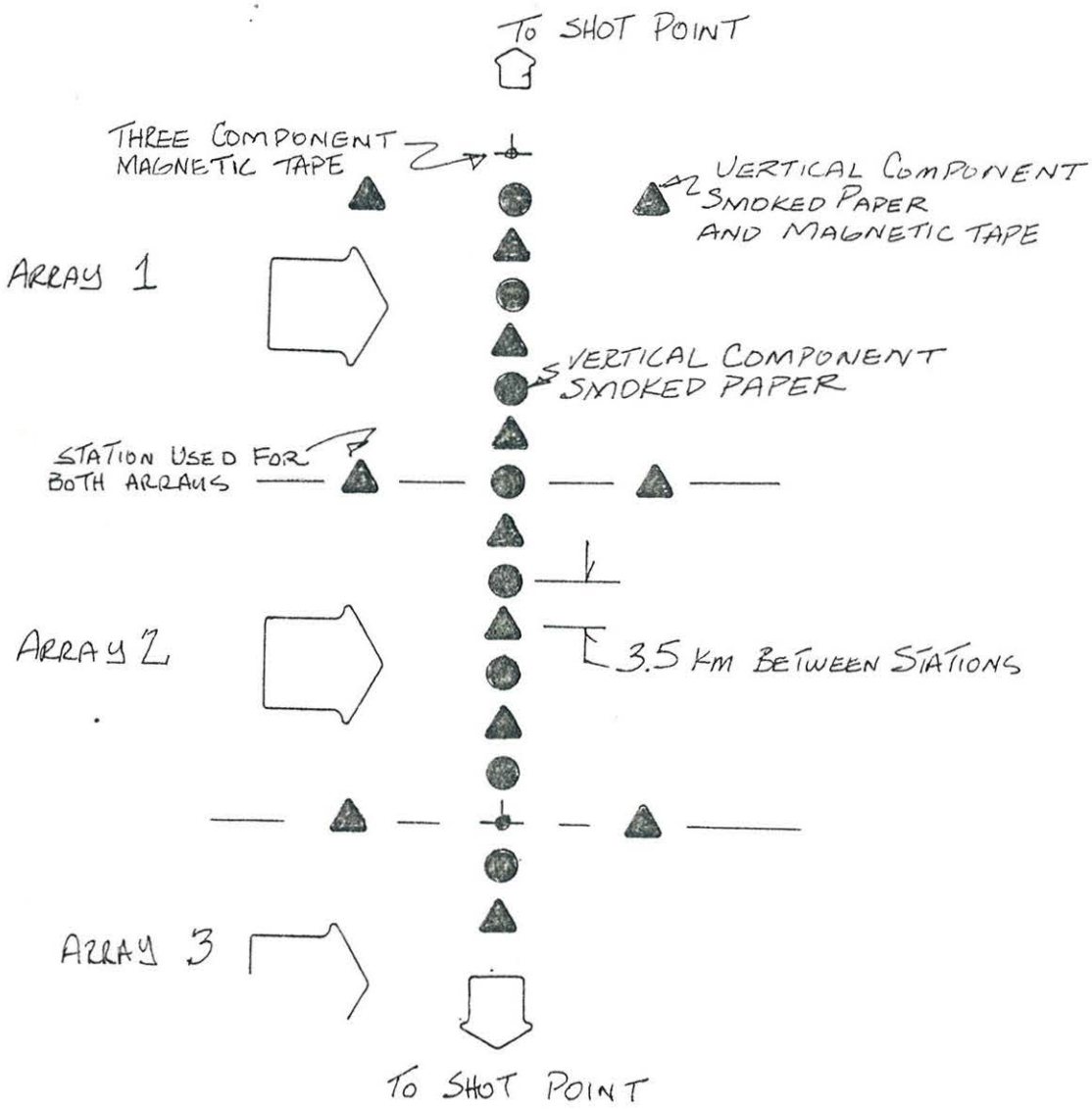
F. Plan of Work

This section will address the field procedures, equipment, and personnel, and expected data rates for the proposed work. It should be noted that this line crosses some of the most rugged topography in the coterminous United States. The weather alone will force the work to be done in July and August. Because of access considerations, the field procedures outlined below are nominal and are subject to modification by the geophysicist-in-charge who will direct the field operation on a daily basis.

The nominal plan of work involves an array of seismic stations to be moved from one shot-point to the next with adequate coverage and overlap of the whole refraction line by the array of stations. On display in Figure 2 are successive arrays which demonstrate the coverage and overlap of the method. Each array has a three-component instrument recorded on magnetic tape at one end, consists of eight in-line stations, and four outlying stations which are used to read the direction of wave front arrivals, and contains a total of 10 components recorded on digital magnetic tape. A total of 14 components are recorded per array, each array covers more than 25 km down the line with the nominal 3.5 km of station spacing. A spacing of 3.5 was chosen in order that single bad recordings can be thrown out without seriously disrupting the continuity of the line. Accurate origin times will be obtained for each



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Each array must record one blast from either end. Blasting at Climax and at appropriate mines in Routt County is a daily occurrence. Optimally, seven recording days would be necessary on the Hayden-Climax line and twelve recording days on the Climax-Questa line. The array can be moved on one day by two men and two vehicles, but to expect the precision of execution necessary to record every day would be foolish. An estimate of forty-field days will be sufficient to obtain the needed data. To facilitate the field effort, one man-month of preparation and permitting is required.

After obtaining the data, the tapes will be played back on the PDP-10 computer of the Colorado School of Mines. Reduced-time-record sections will be prepared, and phases and arrival times estimated. The next step will be preparation of synthetic sections based on models proposed by others or as derived from preliminary interpretation of the sections. The process of synthetic generation and comparison with the observed models will continue until an adequate fit is obtained. Coordination with previous and present work will lead to an integrated interpretation of the tectonics of the area.

One unique feature of this proposed method of study is the use of arrays to record the arrival direction of the seismic energy. Apparent azimuths will be calculated for each phase

and where applicable, the two-dimensionality of the earth will be taken into account. Based on previous work (Crompton, 1976), it is felt that significant deviations from inline propagation will be observed.

Significant attention will be focused on the Dotsero Plume, the Upper Arkansas Valley, and the Upper San Luis Valley as potential geothermal resources. The Rio Grande Rift is a major crustal feature whose velocity and attenuation characteristics are to be investigated.

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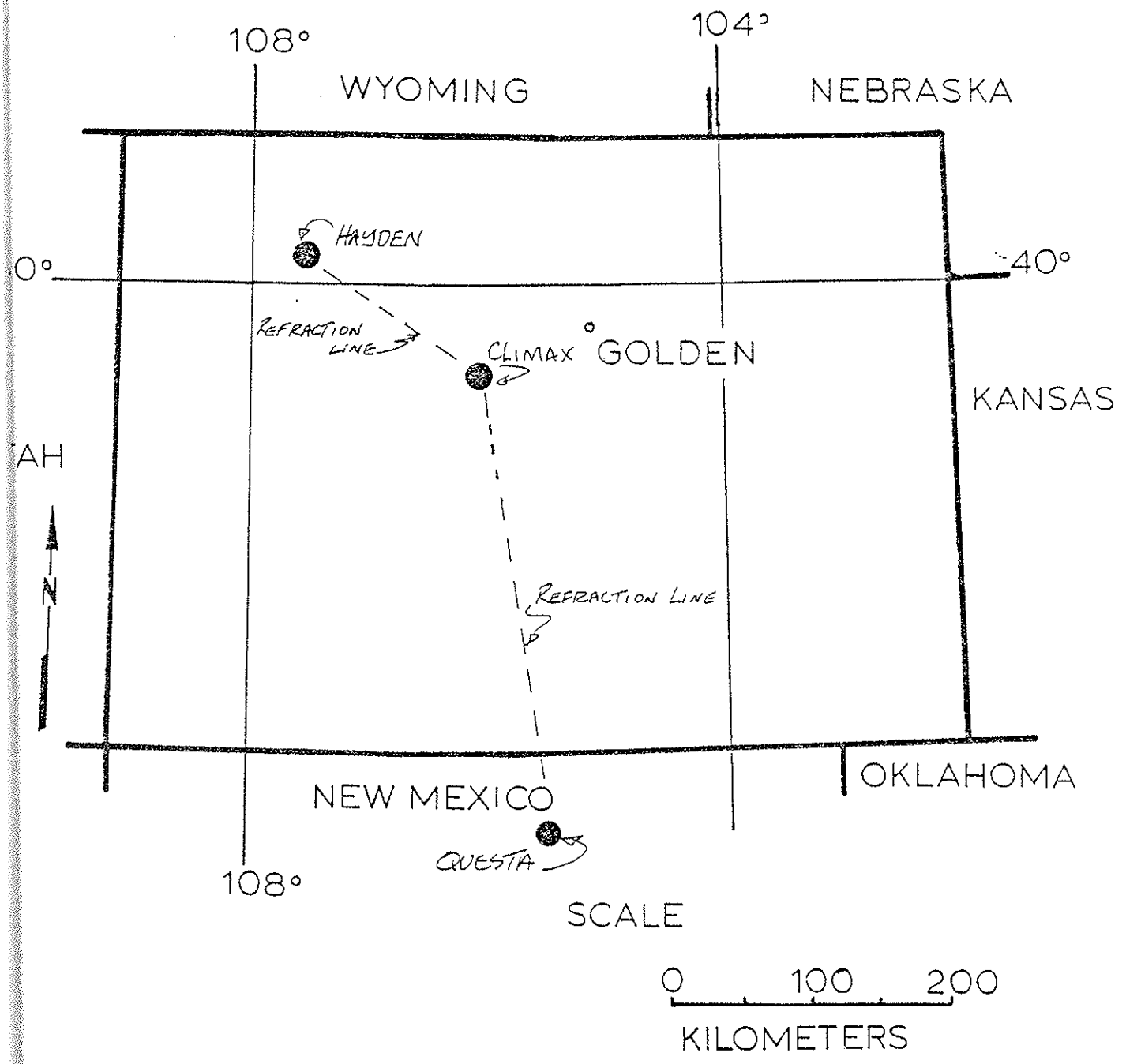

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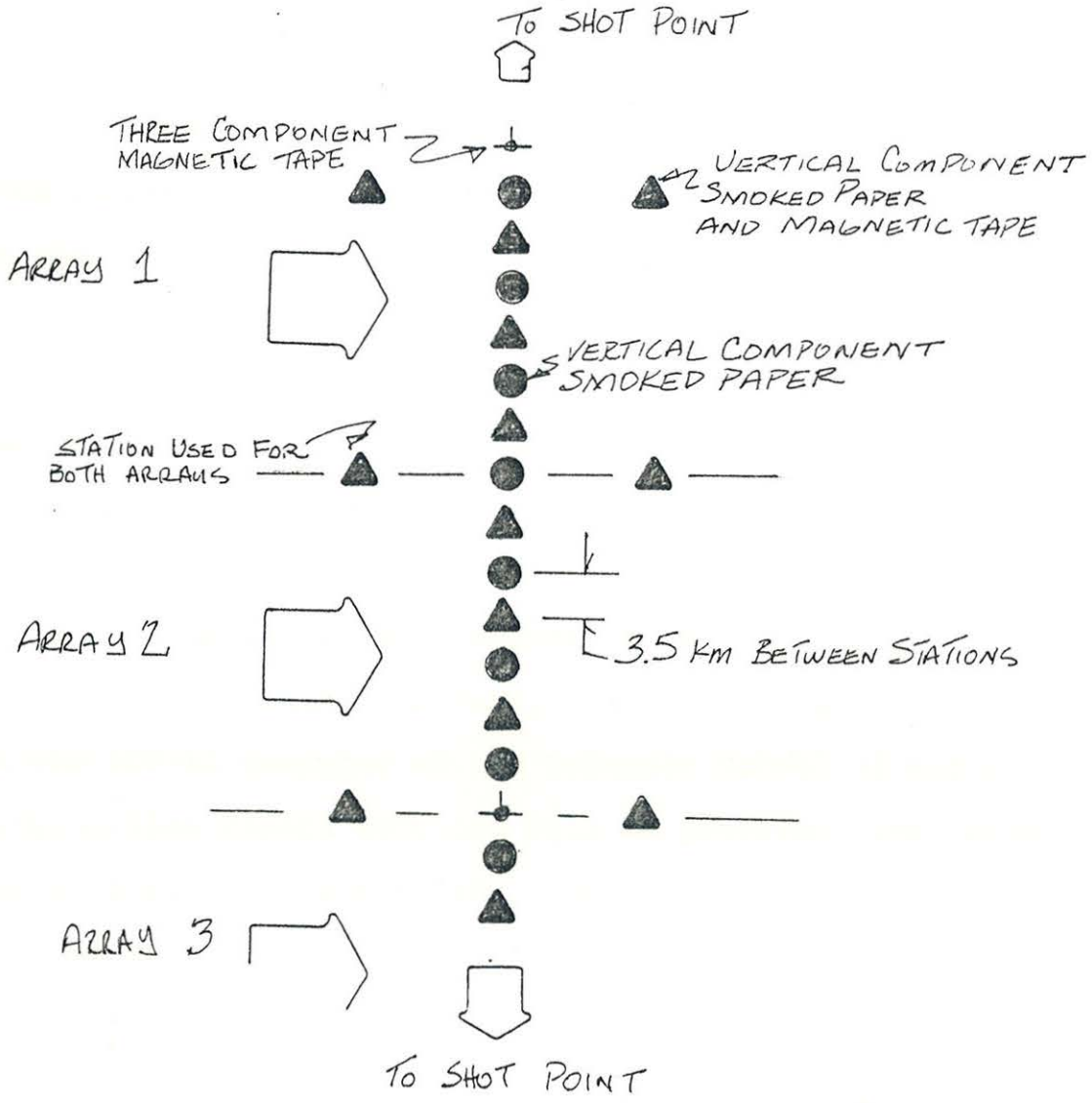

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