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ALEX SCHRIENER
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October 11, 1985

TO: Alex Schriener, Jr.

FM: Angela McDannel AM
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RE: STRUCTURAL ASSESSMENT OF MEDICINE LAKE HIGHLAND

Summary

Structure in the Medicine Lake Highlands (MLH) (Plate 1) is dominated by two major zones that trend north-northeast. The Little Glass Mountain and Lyon's Peak structural trends are characterized by parallel, en echelon ground fractures (or cracks), alignment of explosion craters, fissures, and/or siliceous domes, and linear depressions. These structures probably represent local extension in response to the diapiric rise of magma under the Highlands.

The regional north-northwest and subordinate north-south structural trends (Figure 2) represent Basin and Range block fault tectonism. In the MLH, subordinate, northwest trends are vent alignments which coincide with the regional mode of tectonism. Similarly, alignment of cinder cones surrounding the MLH suggest this trend has influenced recent volcanism. Seismic data (Catchings, 1983; Fuis and Zucca, 1984) from MLH has been interpreted to show that the north-northwest trend continues beneath the Highland. Major north-northwest trending structure(s) beneath the Highland could be a conduit for ascending magma.

The topographic depression which defines the Medicine Lake "caldera" is a constructional basin (Plate 1). The basin is surrounded by volcanoes, vents, and their products and may have

experienced minor passive subsidence as a result of magma withdrawal. There is no evidence that the basin has been down-faulted.

The east-west lineations in the vicinity of Medicine Mountain (secs. 13-17, T43N R3E) and Mt. Hoffman (sec. 31, T44N R4E) are poorly defined, possibly obscured by glaciation, and can not be used to verify a caldera collapse. The discovery of explosion vents (N85°W, N70°W) on the west side of Medicine Mountain and the recent glass flows adjacent to Mt. Hoffman allude to the east-west trends being an older zone of aligned volcanism.

Recommendations

The following recommendations result from the structural assessment of the Medicine Lake Highland:

1. All land along the Little Glass Mountain and Lyon's Peak structural trends should be considered preferred leasing targets. Complete evaluation of temperature and geophysical data within these zones would allow us to prioritize lease land.

2. Coupled (detailed) TDEM surveys should be run over the Lyon's Peak and Little Glass Mountain structural trends and the Medicine Mountain lineation. The purpose of the surveys is to determine the significance, magnitude, and extent of these features and their relationship to structurally controlled permeability. Additional TDEM lines may be required to investigate the intersections of these zones where structurally controlled permeability may be greatest. For the SE corner of the "caldera" these surveys are in progress.

3. Detailed surface structural mapping should be done at MLH to investigate the intersections of the Lyon's Peak and Little Glass Mountain structural trends (NE-SW) with the Medicine Mountain lineation (E-W). The importance of these trends and their intersections and their possible structurally controlled permeability would be imperative to exploration and development drilling there.

Introduction

The purpose of this investigation is to examine structural trends within the Medicine Lake Highland and to establish their relationship to the regional structural setting. The goal is to delineate zones of structural permeability which are targets for exploration drilling.

Structures from the 1:250,000 Alturas sheet (Gay and Aune, 1958), the Fault Map of California (Jennings, 1975), and the geologic map of the Medicine Lake Highland (Hausback, 1983) were used as the base for a fault and lineament map (Plate 1).

Lineaments discovered during the examination of black and white aerial photos (approximate scale 1:68,182) covering an area of approximately 3,200 km^2 (1230 mi^2), were superimposed on this base. A number of these lineaments were field checked to evaluate their structural significance. Other published and unpublished structural information augmented the study.

Regional Structure surrounding MLH

The Medicine Lake Highland (MLH) straddles the boundary between the Cascade and Modoc Plateau physiographic provinces (Figure 1). Both provinces are mantled by Quaternary volcanic rocks. Normal faults are the characteristic mode of tectonism in the region (Hannah, 1977).

The predominate regional structural trend is north-northwest, with less common north-south structures (Figure 2). The structures are Basin and Range-type block faults. Fault traces often show slight and commmonly abrupt changes in strike direction from north to north-northwest or vice versa, but there is no regularity to the direction changes. The faults cut middle Pleistocene rocks (Mertzman, 1977), but appear to be relatively uncommon in late Pleistocene and Holocene lavas.

The Likely fault (Figure 1) is a major north-northwest trending Quaternary feature. It trends N30°-40°W across the central Modoc Plateau for 80 kilometers (50 miles) and is hypothesized to have right-lateral strike-slip displacement (Gay and Aune, pers. comm. in Hannah, 1977). However, field studies (Duffield and Fournier, 1974) have failed to locate evidence of strike-slip motion. The Likely fault's surface expression terminates approximately 40 kilometers (25 miles) east of MLH.

Basin and Range-type faulting is strongly expressed north of MLH (Figure 2), forming grabens such as those containing Tule Lake Sump (T46, 47N R4E) and Klamath Lake (T47N R2, 3E). South of the MLH this type of faulting is also common, but its topographic expression is much less dramatic. Short east-west faults cut the faulted blocks to the north. The east-west faults have small offsets and probably represent local readjustment of the blocks.

The alignment of cinder cones and other vents suggest that the north-northwest and north-south trends have been influential in recent volcanism. Aligned features include the north-south trend of Three Sisters cinder cones (Figure 2, T45N, R2E), a

north-south eruptive fissure (Plate 1, on the boundary between T45N, R3E, sec. 31, and T45N, R2E, sec. 36) (Walter, 1975), and northwest cinder cone alignments (Plate 1, secs. 18, 19, 29, T42N, R4E, and T42 and 43N, R3E) up to 13 kilometers (8 miles) in length.

Regionally, there are few northeast trending faults (Plate 1). Where present, they are short and localized in occurrence. The most noticeable northeast trending features are vent alignments on Fisk Ridge (N52°E, T42N R1E) and Garner Mountain (N38°E and N43°E, T43N R1E), a Pleistocene volcanic center stratigraphically equivalent to MLH volcano. These features are immediately west of MLH, but examination of aerial photos gave no indication of their continuation into or connection with northeast trending MLH structures.

Structure within MLH

In contrast to the regional trend, the dominate structural trend at MLH is north-northeast and northeast. Features with a northeast trend are concentrated along two zones (Plate 1). The most pronounced zone (N22°-30°E) is west of Medicine Lake (secs. 10, 11, T43N R3E) and north of Little Glass Mountain (secs. 18, 19, T43N R2E) and is informally named the Little Glass Mountain structural trend. It is approximately 19 kilometers (12 miles) long and 3 kilometers (1.9 miles) wide and is marked by parallel, en echelon ground fractures or cracks, an alignment of siliceous domes which are believed to have reached the surface via dikes (Fink & Pollard, 1983) and minor eruptive fissures. The second zone, located south of Glass Mountain (secs. 33, 34, T44N R4E) and informally named the Lyon's Peak structural trend, extends approximately 13 kilometers (8 miles). It is narrower and less pronounced than the Little Glass Mountain trend and is characterized by explosion craters, linear depressions, and eruptive fissures. Lineaments with northeast trends occur between the two zones south of Medicine Lake but are very rare north of Medicine Lake.

In the MLH, structures trending approximately east-west are limited to the topographic "caldera" rim. Lineaments and small mapped faults are concentrated on the southern rim. Examination of photos of the north rim revealed only two east-west lineaments located west of Mt. Hoffman.

Minor northwest trends are represented by two vent alignments, located north of Glass Mountain and on the northeast side of Mt. Hoffman.

Field Investigation

Structural features manifested at MLH are ground cracks, vent or dome alignments, explosion pits, and narrow, linear depressions of variable dimensions which are often associated with explosion pits and ground cracks. Very few of the structures are faults marked by a rupture along which offset has occurred.

Few aerial photo lineaments were found to have a significant ground expression. Subtle structural features may have been obscured by widespread forest cover, timber debris, and the ground disturbance caused by extensive logging. Some lineaments seen as continuous features on aerial photos were found to be discontinuous, approximately linear topographic breaks associated with primary features of lava flows.

Previously unrecognized but structurally significant lineaments were located southwest of Medicine Mountain in sections 16 and 20 of T43N, R3E. Multiple, parallel ground cracks up to 130 meters (425') long and 5 (or more) meters (15') deep trend N25°-40°E over an area of approximately 200 m^2 (2200 $ft.^2$) in the southwest corner of section 16. The andesite in which the cracks formed exhibits glacial striations and polish on its surface, but the walls of the cracks have not been affected, suggesting that cracking was post-glacial. These ground cracks are not visible on aerial photos.

Other cracks and linear depressions were found that are associated with the Little Glass Mountain structural trend. A lineament (identified from aerial photos) which lies west of Red Hill (sec. 29, T43N, R3E) exhibits subtle, discontinuous depressions trending approximately N30°E for almost three kilometers (1.9 miles). Similar features form lineaments in nearby areas (secs. 20, 30, 31, T43N, R3E, and sec. 36, T43N, R2E).

East-west and northwest trending lineaments bordering the caldera-like Medicine Lake basin are of interest because they may be evidence for basin subsidence along faults. No ground evidence was found for the north-south trending lineaments east of Red Shale Butte (secs. 8 and 17, T43N, R3E) on the east side of the "caldera". The long east-west trending lineaments west of Mt. Hoffman (secs. 35 and 36, T44N, R3E) and on Medicine Mountain (secs. 14 and 15, T43N, R3E) were likewise disappointing.

Field evidence is equivocal for previously mapped east-west trending faults (Hausback, 1983) atop and on the south side of Medicine Mountain. Caution should be exercised when using these structures as evidence of subsidence or resurgence. The faults, trending approximately east-west, are based upon escarpments which are interpreted to be too high for flow fronts and lacking the arcuate morphology of glacial cirques. The steep scarps represent only part of the faults' lengths and offset beyond the scarps is difficult to document.

Small east-west trending lineations were observed at the west end of Medicine Mountain. A short lineament in the SW 1/4 of section 15, T44N, R3E is interpreted to be an explosion pit and associated linear depression. The trend of this feature is N85°W. A similar explosion feature occurs south of center of section 16 (T43N, R3E) and has a trend of approximately N70°W. Both of these explosion features occur in Rampart andesites and do not appear to have been formed during an eruptive event, as no lava is associated with them. The abundance of vegetation and rock fill in the blast craters leads to the interpretation that they are older than the explosion pits of the Lyon's Peak structural trend.

Subsurface Structural Information

Geological

Correlation of lithologic data from the numerous wells drilled at MLH is not useful for detecting small (less than 160 m (525') of offset) subsurface structures. This is due to the distance between wells and the correlation of thick, generalized rock types rather than individual lavas. Large through-going structures at MLH have not been found in the examination of well data (R. Gunderson, pers. comm.).

Geophysical

Seismic refraction experiments conducted in the Modoc Plateau and Cascade provinces (Catchings, 1983; Fuis and Zucca, 1984) reveal large-scale north-northwest sub-surface structures in the MLH area. A two dimensional velocity model interpreted from seismic data collected along a refraction line from Big Valley to Butte Valley (Figure 1) suggests that valley bounding faults (following the north-northwest regional trend) extend into basement rocks. This indicates that the block faulting north and south of MLH is a significant structural feature at depth.

Beneath MLH there is a velocity discontinuity which suggests that the southeast side of the highland is downdropped approximately one kilometer relative to the northwest side.

Repeated changes in velocity boundaries at depths up to 22 kilometers suggest a major geologic discontinuity such as a fault or suture zone occurs beneath MLH (Catchings, 1983). Although a trend for this structure is not indicated by the data, its detection requires that its strike not be coincident with that of the seismic line (approximately N40°W).

Discussion

Regional northwest and north trending Basin and Range block faults cut Tertiary and Quaternary rocks and have controlled volcanism as recent as Holocene. The faulting is the result of northeast-southwest to east-west extension which characterizes the regional stress regime of northeastern California. Major north and northwest trending faults appear to intersect at MLH (Figure 2). Seismic data indicates that major faults of this trend extend into basement rock and, therefore, should provide convenient conduits for ascending magma.

Northeast structural trends predominate at MLH and the area immediately west of MLH. The reason for localized northeast trends is unclear. Volcanism typically follows rather than causes a structural trend, a fact that seems particularly obvious when vents are localized in long, narrow linear zones. At MLH volcanic processes may be creating a localized stress regime uncharacteristic of the regional stress field, or utilizing older structures that have little surface expression. It is possible that the extension mechanism creating the Little Glass Mountain and Lyon's Peak trends is caused by the diapiric rise of magma. Rifting of this nature will occur as long as the near surface crust is able to extend freely (Mulugeta, 1985). In light of the regional tectonics at MLH this is plausible.

The east-west lineations in the vicinity of Mt. Hoffman and Medicine Mountain are poorly defined and possibly obscured by glaciation and recent volcanism. The lineations can not be used to verify caldera collapse. The discovery of explosion vents (N85°W, N70°W) on the west side of Medicine Mountain and the recent glass flows adjacent to Mt. Hoffman allude to the east-west trends as being former zones of aligned volcanism and local extension.

The apparent lack of faults surrounding the topographic low containing Medicine Lake casts doubt on the possibility that this depression is actually a caldera formed by subsidence. It seems more likely that the topographic highs surrounding this low are the result of constructive volcanism.

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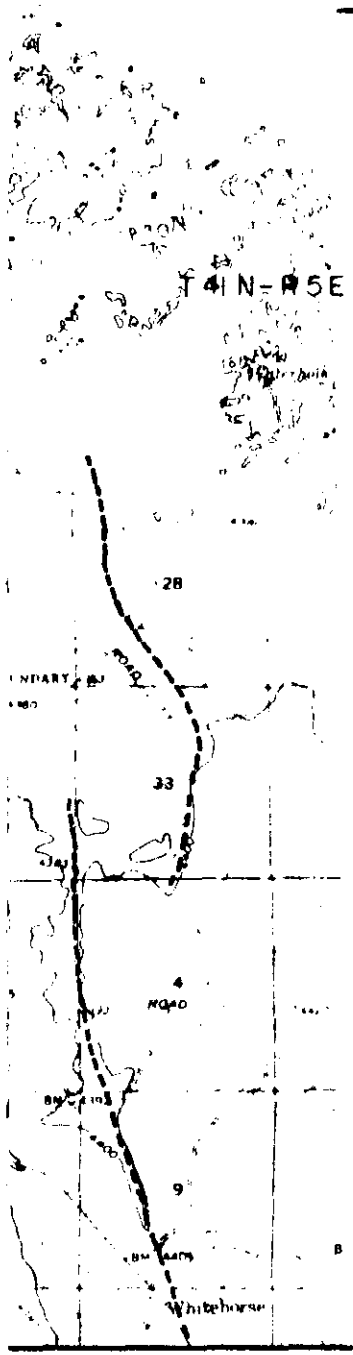

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GEOTHERMAL DIVISION
LOS ANGELES CALIFORNIA

GLASS MOUNT PROSPECT FAULT AND LINEAMEN

BY ANGELA McDANNEL

PLATE 1
SISKIYOU AND MODC
COUNTIES, CALIFORN

SCALE : 1" = 1 MILE

Original Map in Folder
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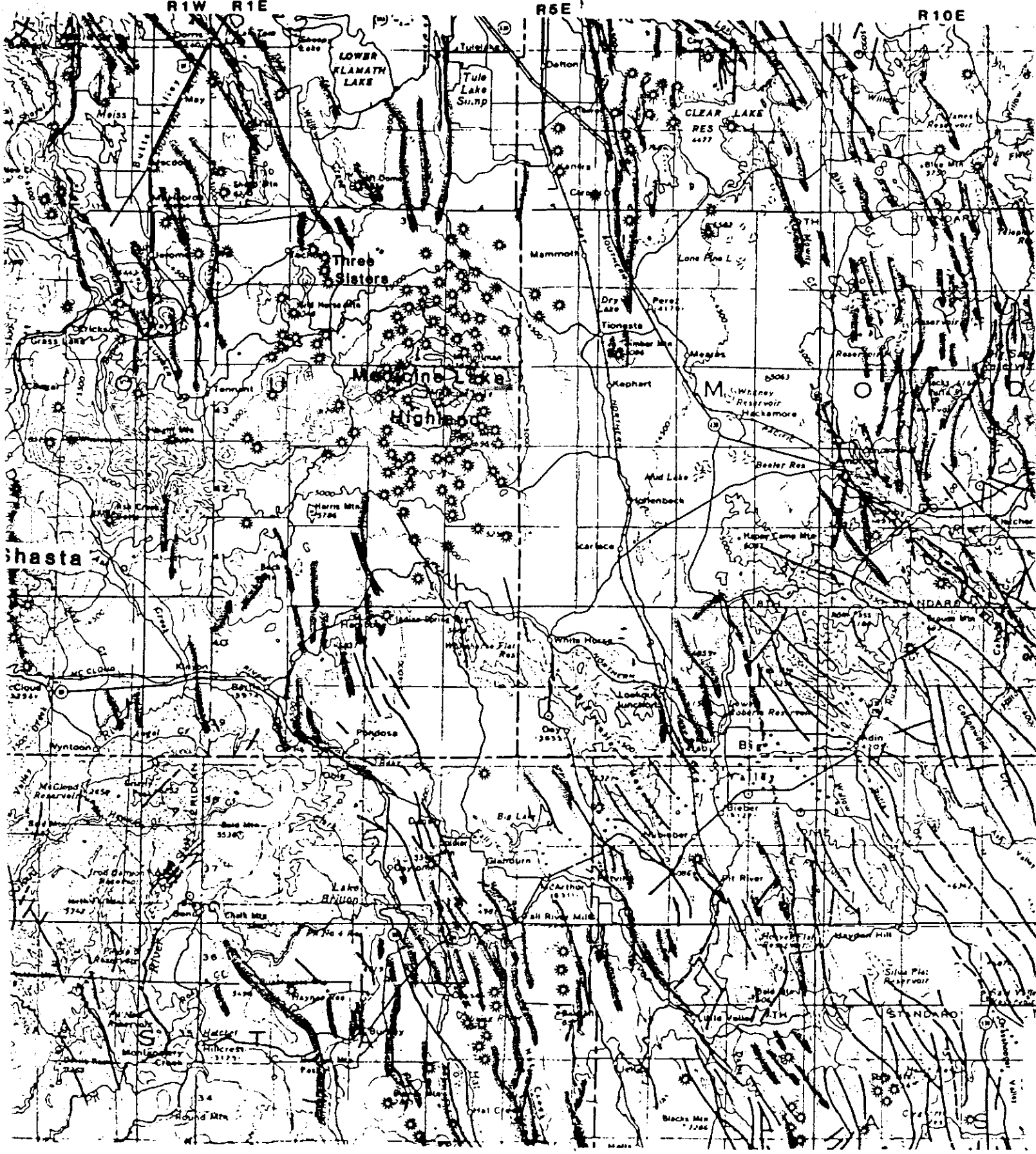

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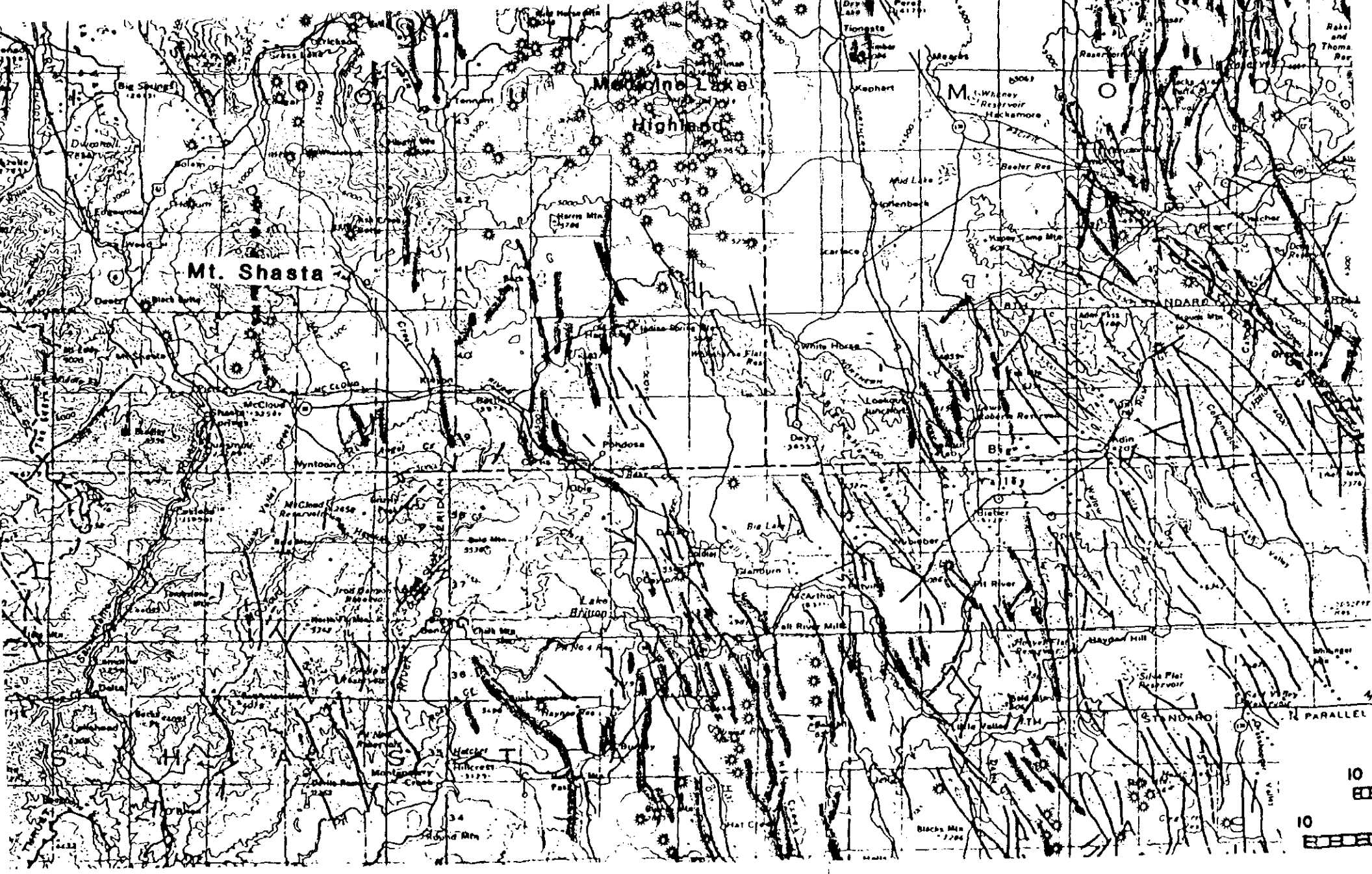

FIGURE 2. Regional fault trends in the Modoc Plateau and Cascade Range provinces, northeast California. Shaded faults show Quaterr
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