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HCMM - SOIL MOISTURE IN RELATION TO GEOLOGIC STRUCTURE AND LITHOLOGY, NORTHERN CALIFORNIA

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16. Abstract

HCMM images of about 80,000 km^2 in northern California were qualitatively evaluated for usefullness in regional geologic investigations of structure and lithology. The thermal characteristics recorded varies among the several geomorphic provinces and depends chiefly on the topographic expression and vegetation cover. Identification of rock types, or groups of rock types, was most successfully carried out within the semi-arid parts of the region; however, extensive features, such as faults, folds and volcanic fields could be delineated. Comparisons of seasonally obtained HCMM images were of limited value, except in semi-arid regions.

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PREFACE

(a) Objectives: the objectives of the project were to qualitatively assess the value of the HCMM thermal imagery as applied to regional geologic interpretation of structures and lithologies in northern California. The study was based on the probable seasonal soil moisture changes as a function of the bedrock type. An additional objective was to delineate known geothermal areas in the region.

(b) Scope of the Work: HCMM images were reviewed to attempt to relate recognizable thermal characteristics with known geologic features and to compare the data with published geologic maps.

(c) Conclusions: The regional geologic analysis has demonstrated that the interpretability of the HCMM images for geologic purposes is overwhelmingly influenced by surface topography and vegetation cover; but the images might be most useful in arid or semi-arid regions where the underlying rocks are not masked by thick soil or vegetation.

(d) Recommendations: Future work should concentrate on the improvement in the scale and resolution of the images and to improve the quality of the products furnished.

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INTRODUCTION

The objectives of the project was to qualitatively assess the value of the HCMM thermal imagery as applied to regional geologic interpretation. The study focused on the seasonal variation in the thermal characteristics of geologic structures and lithologies, of natural soil moisture as related to the underlying geology and of known geothermal areas.

The study area, located in northern California, encompasses about 80,000 Km^2 and includes a variety of complex topographic and geologic terrains, a number of distinct climatic regimes and a diverse vegetative cover. A thorough examination of specific geologic features provided the conceptual framework, which allowed an evaluation of the general regional relationships within the area.

METHOD OF STUDY

Data Available:

1. The project received about 500 separate images of which less than 5% were of usable quality. The photographic quality of the HCMM images varied considerably in graytone characteristics, so that it was possible to make onl crude comparisons between images taken a different times of the year. Cloud- and fog-cover on many of the images, particularly the Nite IR, further reduced the usefullness of the HCMM data for geologic interpretation. The earliest images available were from the spring of 1978 and were obtained near the end of a two-year drought in California; hence, these images may not reflect the thermal characteristics representative of normal weather conditions. Among the various types of images, the

Day Visible and Nite IR proved to be most useful for purposes of lithologic, structural and drainage analysis. Except in a few cases, the Day IR, Thermal Difference and Apparent Thermal Inertia images yielded only very limited amount of additional information.

2. NASA Aircraft underflights: The project utilized previously obtained NASA Aircraft photography during the course of the investigation. These photos were of a 30 - 40 mile wide east-west test strip centered along the 39°00' parallel in northern California.

   The pre-launch data from the underflights were examined in detail in order to establish photogeologic criteria for the various lithologic and structural details within the various micro-climatic regions. During the course of the project, comparison of the HCMM images with the underflight photography was used extensively.

3. Landsat imagery was available for the entire region and was used extensively for pinpointing recognizable vegetaion changes and as a check on specific geologic features or characteristics to be examined on the HCMM imagery.

Equipment:

The equipment used to examine the HCMM images was of the simplest type. In addition to the usual photo interpretive equipment, such as light tables and binocular microscope, the images were projected onto a translucent frosted glass screen mounted in a movable frame. The projector was a standard 'over-the-counter' type 3 1/4" x 4 1/4" classroom lantern slide projector. The area to be studied was cut from one copy of the positive transparencies and mounted between glass plates. A second copy of the image was filed for reference purposes.

The images could be effectively enlarged to a scale of about 1:500,000; however, because of the loss of resolution at this scale, a working scale of 1:1,000,000 was established.

Correlation of Geologic Data:

The Principal Investigator had geologically mapped a small part of the project area, but he has limited detailed knowledge of other parts of the area. For those regions unfamiliar to the Principal Investigator, the information obtained from the HCMM images was compared with published geologic maps and with Landsat images.

SCIENTIFIC RESULTS

Introduction:

The predominiant geologic and topographic trend in northern California is north-northwest (Figure 1) and it is apparent that this trend effects the regional thermal characteristics as depicted on the HCMM imagery. Superimposed on the general trend are several distinct geomorphic provinces, each province exhibits a unique topographic expression and unique microclimatic characteristics. The principle terrestrial influence on the thermal characteristics observed on the HCMM imagery was found to be topography. The diurnal thermal variations interact with a given topographic regime to produce the local microclimatic effects most readily observed on the HCMM imagery. The more subtile thermal effects due to structure, lithology and soil moisture can be recognized only when the effects of topography have been determined and taken into account. Consequently, each of the several geomorphic provinces were analysed separately.

Figures 2 and 3 are Day IR and Nite IR images obtained on May 31 and May 30, respectively, and Figures 4 and 5 were obtained on October 6 and October 5, 1978 respectively. These images will be referred to throughout the remainder of this report.

Northern Coast Ranges:

The present land surface in the northern Coast Range (Figure 1) varies in elevation from sea level along the coast to a maximum of about 2600 meters at the crest of the range. Along the eastern slope, the elevation decreases to about 300 meters. The annual precipation ranges from about 100 cm along the coast to about 80 cm near the crest and about 50 cm along the leeward side of the range. In general, the kind and amount of vegetation changes with elevation and precipation. Along the coast, the vegetation consists chiefly of redwood and conifer forests, with localized brush and grasslands. On the western slopes, the vegetation changes to conifer forests and these forests constitute the bulk of the vegetation within the northern Coast Range. Brush and scrub oak predominate on the leeward slope.

The geology of the Coast Range is complex and bedrock exposures are rare. Thus, the thermal characteristics in this area are influenced chiefly by topography and vegetation. The influence of geology upon the the thermal spectrum is limited; however, a few geologic features are nevertheless discernable on the Nite IR images.

The bedrock in the Coast Range consists chiefly of metasedimentary and sedimentary rocks of Mesozoic age that locally have been intruded by serpentinite. In some areas, the Mesozoic rocks are overlain by Tertiary

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Figure 1 Landsat Mossaic of Northern California

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Figure 2 HCMM, Nite IR, May 30, 1978, # A-A0034-10201-3

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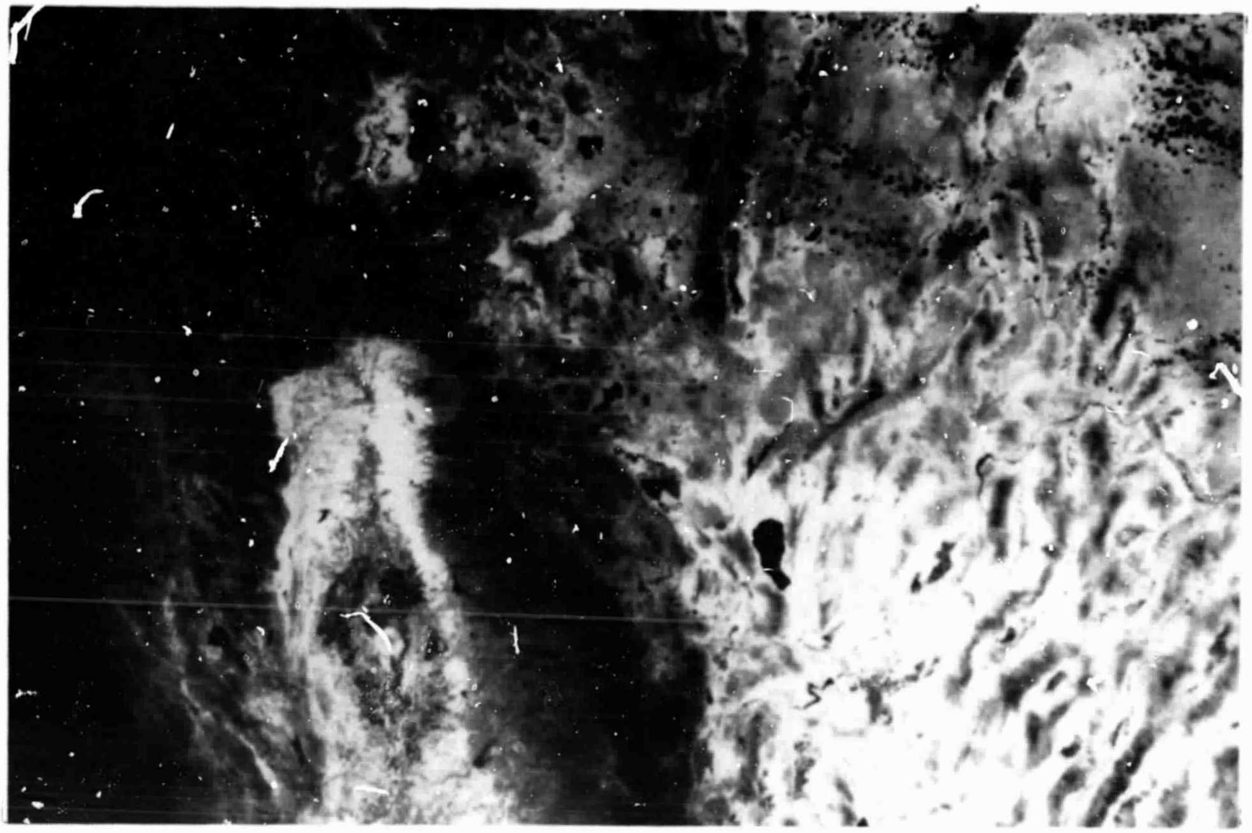

Figure 3 HCMM, Day IR, May 31, 1978, #A-A0035-21330-2

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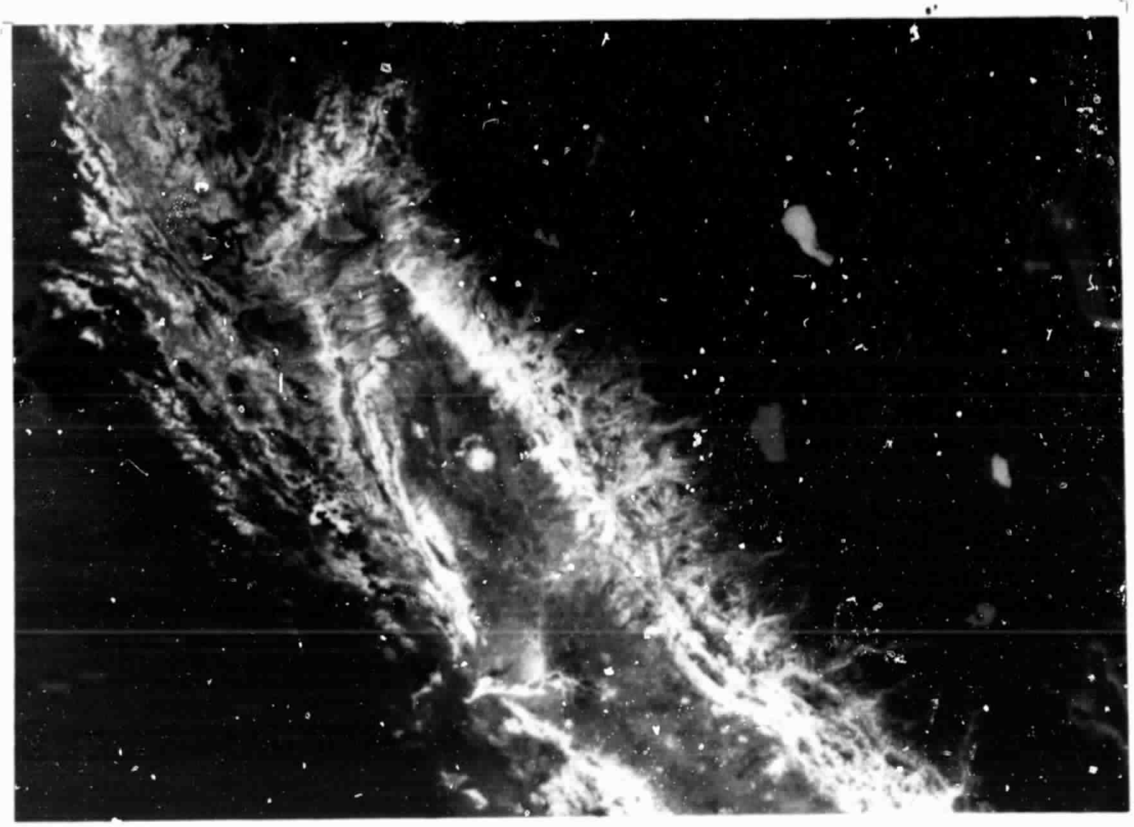

Figure 4 HCMM, Nite IR, October 5, 1978, #A-A0162-10040-3

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Figure 5 HCMM, Day IR, October 6, 1978, #A-A0163-21160-2

volcanic flows. All of these rocks have undergone structurally complex deformation and represent the melange belt along the Pacific Coast. The principal structural elements are northwest-trending faults and fractures, subparallel with the present trend of the San Andreas Fault.

Attempts to segregate specific rock types, or groups of related rock types, on the HCMM images were largely unsuccessful; however, lineations related to the northwest-trending faults and fractures are clearly discernable (Figures 3 and 5). Inasmuch as these lineations coincide with known topographic expressions of faults and fracture systems, it is thought that the representation on the HCMM images is more directly related to topography than to any unique thermal properties related to the faults. Analysis of the HCMM images taken at various times of the year do not disclose any thermal characteristics that could be related directly to rock types or structural elements.

The northern Coast Range contains one of the world's largest producing geothermal fields -- the Geysers; however, no evidence of thermal areas could be detected on the HCMM images received by the project, regardless of the time of year the images were obtained.

In summary, the ability to detect differences in rock types or geothermal areas within the northern Coast Range is of extremely limited value. Although some linear elements could be detected, it was thought that these lineaments are more directly related to the topographic effects on the imagery than to any inherent thermal properties related to structure or to rock type.

Sacramento Valley:

The land surface within the Sacramento Valley ranges in elevation from 350 meters above sealevel around the margins of the Valley to about 30 meters near the axis of the Valley. The annual precipitation ranges from 40 to 50 cm and the area is classified as semiarid. The vegetation along the margins of the Sacramento Valley consists of grasslands with local areas dominated by scrub oak and/or dense brush. The central part of the valley is irrigated and intensely cultivated.

A ridge and valley topography, developed on homoclinally dipping interbeds of marine sandstone and shale of Mesozoic age, dominates the southwestern margin of the Valley. In contrast, the topography along the northwestern margin is represented by a gently east-dipping surface developed on late Tertiary to Recent alluvial fans. The central part of the Valley is a relatively smooth south-sloping surface developed on thick alluvial material deposited by the Sacramento River during Pleistocene to Recent time. The eastern margin of the Valley is defined by the trend of the Chico Monocline and the land surface rises abruptly at the monoclinal axis. East of the monocline, the topography is a relatively smooth west-sloping surface into which deep canyons have been incised. The bedrock across the monocline is interbedded basaltic- to andesitic-lava flows, pyroclastic and lahars (volcanic mudflows). The northern end of the Valley is rimmed by an irregular hilly topography developed on sedimentary and metasedimentary rocks of Paleozoix to Mesozoic age.

Within the region of ridge and valley topography along the southwestern margin of the Valley, the massive sandstone beds that underly the ridges can be clearly delineated from the intervening shale beds that underly the valleys on some of the Nite IR images (Figures 2 and 4). This can best be seen on images taken during the spring growing season. Analyses of several images taken during this time period suggest that the different soil moisture conditions between the more porous sandstone beds and the partly impermeable shale beds ma account for some of the tonal differences observed on the HCMM imagery; however, these effects are not easily separated from the tonal differences arising due to topographic expression. Furthermore, the tonal expression was not apparent on every image taken during the time period. Depending on the quality of the image reproduction, the weather conditions prevailing at the time the image was obtained and the previous weather history, the certainty of interpretation was seriously affected.

Subtle tonal differences were observed on the alluvial fans that border the northwestern margin of the Valley. When compared with the geologic maps of the area, these tonal differences appear to be related to two episodes of alluvial fan development. The older fans (Plio-Pleistocene in age) appear to exhibit a graytone slightly darker (cooler) than that observed on the recently building fans. These tonal differences were more pronounced on the Nite IR images taken during the late summer or early autumn (Figure 4). Inasmuch as no obvious difference in vegetation or topography exist between the two generations of fan development, the tonal difference is attributed to retained soil moisture. The older fan material is more indurated and probably retains more moisture throughout the summer than does the relatively loosely compacted sand and gravel on the more recent alluvial fans. Again, no consistency of this phenomenon could be observed on all HCMM imagery, even within a few days time span.

Along the northeastern margin of the Sacramento Valley, the axis of the

Chico Monocline is defined on many of the Nite IR images as a sharp linear tonal change from medium- to light-gray tonal value west of the axis to very light-gray to white tones on the east (Figures 2 and 4). This tonal change may reflect subtle changes in the surface moisture resulting from the down-dip or downslope migration of groundwater released along many fractures at the crest of the monocline. Landsat images and air photos do no indicate any marked vegetation changes along the axis. Previous field investigations by the Principal Investigator during late summer months disclosed that a distinct set of fractures exist along the axis and very locally they appear to be the loci of surface water seeps. This observation cannot adequately account for the continuous linear tonal change observed on the HCMM images because the seeps are too snall and too localized to be expresses at the scale of the imagery.

As indicated previously, no lithologic change is apparent on either limb of the monocline and this is substantiated by air photo and field observations. Further, no definitive thermal characteristics related to bedrock could be found on the HCMM imagery in adjacent areas not effected by folding. The tonal change may reflect, to some extent, the abrupt change in topographic relief and to the angle of exposure of the west-facing slope, because the slope is relatively warmer during the day (Figure 3) and cooler at night (Figure 2 and 4). Thus, the linear feature seems to be related to a combination of factors - - soil moisture and topographic exposure.

One of the objectives of the project was the possible recognition of buried stream channels beneath the alluvial deposits within the central part of the Sacramento Valley. This objective was not successful; partly because the intensively irregated ground masked any subtle natural moisture variations that might have existed and partly because of the small scale and resolution of the images. An attempt was made to evaluate the thermal characteristics of the irrigation patterns to determine whether or not the various episodes of irregation during the summer might be related to plant stress and hence possibly reflect subsurface moisture conditions. This investigation was unsuccessful.

A small igneous intrusion within the Sacramento Valley (Marysville Butte) is clearly evident on some of the HCMM images. On a few images, for example Figure 3, it was possible to differentiate the igneous core (dark-gray tone) from the surrounding upturned Mesozoic and Tertiary sedimentary rocks. However, it was not possible to differentiate specific rock types within the sedimentary sequence nor to detect small faults that are known to transect the Butte.

Modoc Plateau:

The land surface within the Modoc Plateau ranges in elevation from about 350 m along the axis of the Chico Monocline to about 2500 m, with a maximum of about 3000 m at the top of the higher volcanic peaks. The vegetation consists chiefly of conifer forests with intersperced brushlands. In the higher elevations, the region receives about 100 cm of precipitation, mostly in the form of winter snow. The eastern and western margins of the plateau receives about 50 cm of precipitation.

The Modoc Plateau, in northeastern California, is made up of thick and widespread andesitic to basaltic lava flows, pyroclastic deposits and lahars of Pliocene age and volcanic cones of Plio-Pleistocene age. The most prominent volcano is Mt. Lassen which was last active in the late 1920's. The region contains several hot spring areas and locally extensive geothermal areas. The region underwent extensive glaciation during the Pleistocene and hence many of the landforms reflect glacial erosion during that period.

Attempts to differentiate the various lava flows from the HCMM images was generally unsuccessful; although, on some of the images, the outlines of flows (defined by thermal characteristics) were observed. However, the delineation of the flows from the images was doubtful because the outlines of these flows changed from image to image or was not evident at all.

On some of the Nite IR images (Figure 4) the larger volcanoes were clearly evident. The thermal characteristics consist of cool (dark) regions around the base of the volcanoes, a warmer (light) band around the flanks and a small circular cool (dark) zone at the crest. This relation suggests that debris accumulated at the base of the volcanoes consists of clayey alluvial material which retains more moisture than the flanks of the volcanoes which are underlain by coherent volcanic rock. The small circular cool part at the crests of the volcanoes may represent small depressions which contain alluvial material washed from the sides of the depressions. Alternatively, since the warmer areas along the flanks of the volcanoes appears to be at about the same elevation (although the warmer area appears to move upward or downward, depending on the season of the year), the phenomena may be the result of atmospheric layering. Atmospheric layering was observed within many of the stream valleys along the western front of the Modoc Plateau and the Sierra Nevada and around the fringes of many of the intermontaine basins in the Great Basin of Nevada. A similar atmospheric layering effect may explain the systematic thermal variations observed on the volcanoes of the Modoc Plateau.

Several geothermal areas are known to exist within the Modoc Plateau.

Definitive criteria to delineate these areas from HCMM imagery were not found.

The junction of the southern boundary of the Modoc Plateau and the northern boundary of the Sierra Nevada is geologically rather sharp and consists of the juxtaposition of volcanic rocks of the Plateau against the granitic plutonic and metamorphic rocks of the Sierra Nevada. The Sierra Nevada province is characterized by many deeply incised stream valleys that, in general, trend southwestward; whereas the Modoc Plateau is characterized by a derranged drainage pattern in the east-central part and by a fine-textured linear pattern along the western margin. On the basis of the observed thermal layering within the stream valleys on the Nite IR images, the junction of the two provinces could be deduced by the change in drainage patterns. This observation depends on the differences in topographic expression rather than on any thermal effects due to different lithologic units.

Summary:

The thermal IR characteristics of the HCMM images varies among the geomorphic provinces within northern California and in some instances within a single province. Each province has a few specific features that can be delineated on the HCMM imagery. For example: 1) linear features representing faults or fracture zones may be recognized, and locally used to suppliment current ground information, within the northern Coast Ranges; 2) thermal characteristics along the margins of the Sacramento Valley, a semi-arid environment, can be directly related to the varying lithology and structural elements; and 3) volcanoes within the Modoc Plateau can be identified by their unusual thermal characteristics.

CONCLUSIONS

The results of this investigation can be summarized as follows:

1) Topographic expression and vegetation type and density appears to have the greatest influence on the thermal characteristics recorded on the HCMM images. These characteristics may give clues to the underlying bedrock and geologic structure, if used with extreme caution;

2) Seasonal variation in the thermal characteristics of geologic features, as reflected on the imagery, were not as useful for geologic interpretation as was anticipated. Either the weather condition (or history) at the critical times of the year was not appropriate or the quality of the imagery was uncertain. These qualifications can be a hindrence to the geologic interpretation of a region;

3) Evaluation of the images taken over semi-arid regions in northern California suggest that, for geologic purposes, the HCMM imagery might be most useful for lithologic and structural studies of arid or semi-arid regions where bedrock is not masked by thick soil or vegetation cover;

4) On none of the images could the extensive and well known geothermal areas within Northern California be recognized;

5) The scale and resolution of the imagery was not adequate for detailed geologic work but the images might be used, within appropriate limits. for areal reconnaissance on a regional scale to extract potential clues for more careful studies;

6) The thermal Difference and Apparent Thermal Inertia images provided to the project were of extremely limited value for qualitative geologic interpretations.