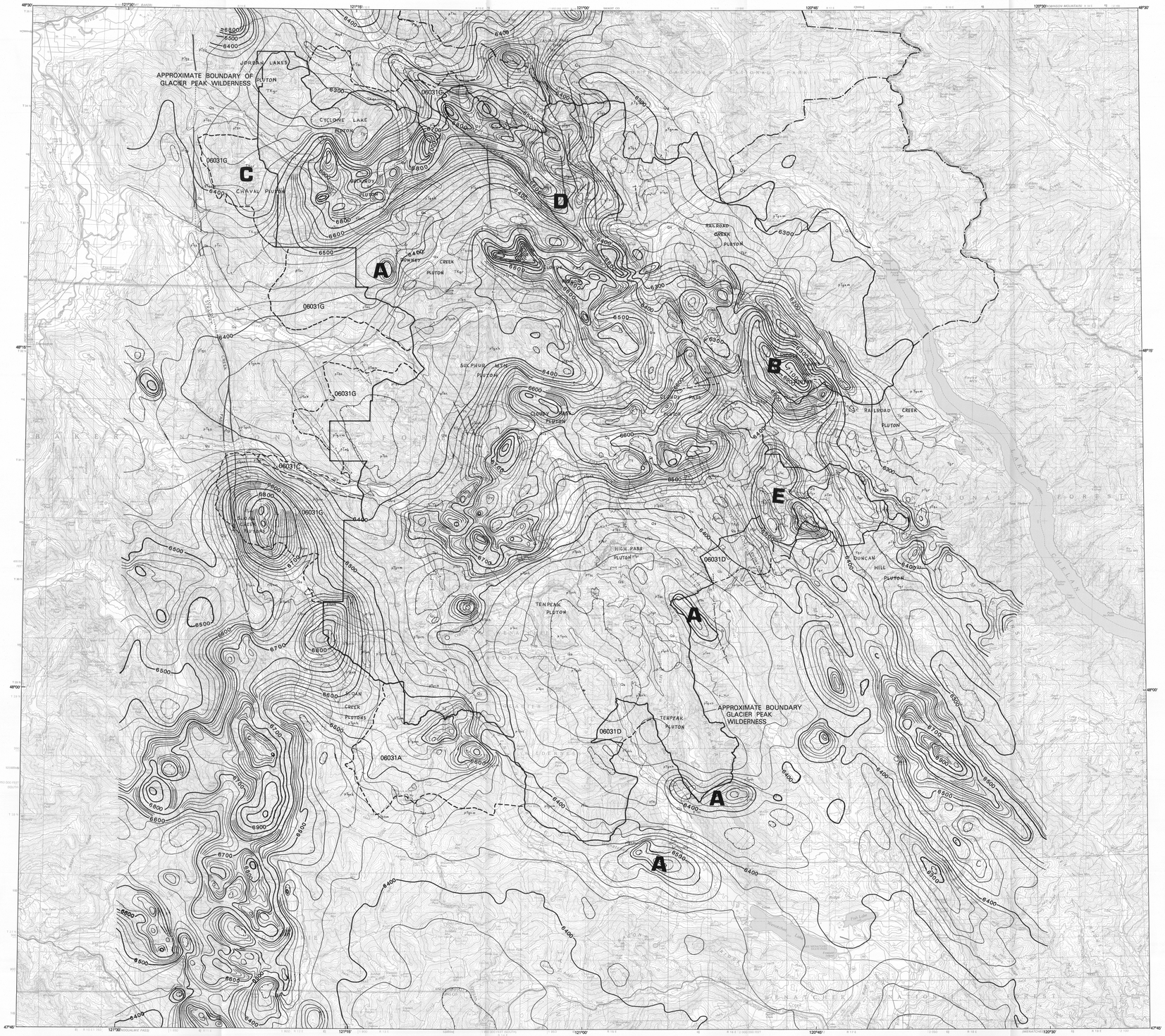
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1652-B



Base from U.S. Geological Survey
Skykomish River, 1973; Chelan, 1973;
Twisp, 1978; Sauk River, 1978

SCALE 1:100 000

Geology compiled from sources shown by Ford (1983, fig. 2); with additional mapping by A. B. Ford and R. A. Sonnevil in 1980–82, W. H. Nelson and R. A. Loney in 1980–81, Carl Hale and R. A. Haugerud in 1980, and S. L. Garwin in 1982

AEROMAGNETIC MAP OF THE GLACIER PEAK WILDERNESS AND ADJACENT AREAS, CHELAN, SKAGIT, AND SNOHOMISH COUNTIES, WASHINGTON

By

Vincent J. Flanigan and Mark Sherrard

1985

EXPLANATION

3600 — MAGNETIC CONTOURS—Showing total-intensity magnetic field of the Earth in gammas, relative to arbitrary datum. Hachured in areas of closed magnetic lows. Regional magnetic gradient has been removed. Contour interval 20 gammas

APPROXIMATE BOUNDARY OF GLACIER PEAK WILDERNESS

06031A — APPROXIMATE BOUNDARY OF AREAS OF RECOMMENDED WILDERNESS ADDITION

(Note: The following correlation, description of map units, and list of symbols are for the geologic base map shown here in gray.)

CORRELATION OF MAP UNITS

Qs, Qva	Qv		QUATERNARY
Tv	Tt	Tgr	TERTIARY
Ts		TKgr	CRETACEOUS TRIASSIC
Pzgn			PRE-TERTIARY

Relative positions and age uncertain

pTgr pTga pTgn pTgnh pTgnm pTsc pTga pTnh pTum

Qs — SUPERFICIAL DEPOSITS (QUATERNARY)—Mostly unconsolidated alluvium, colluvium, and glacial materials. Includes reworked volcanic ash and pumice of postglacial eruptions of Glacier Peak volcano

Qva — PYROCLASTIC AND VOLCANIC SEDIMENTARY DEPOSITS (QUATERNARY)—Mostly unconsolidated materials derived directly from Glacier Peak eruptions. Includes deposits from mudflows and ash flows

Qv — VOLCANIC ROCK (QUATERNARY)—Lava flows and breccia of dacitic to andesitic composition of Glacier Peak, and olivine basalt of small vents south of Glacier Peak

Tv — VOLCANIC ROCK AND PORPHYRY (TERTIARY)—Generally altered rock, breccia, and volcanic sedimentary materials of dominantly andesitic composition. Includes complexes of dikes and plugs

Tt — GRANITIC ROCK (MIOCENE)—Medium-grained, commonly porphyritic, biotite-hornblende granodiorite and granodiorite

Tgr — GRANITIC ROCK (TERTIARY)—Granitic rock, undifferentiated

Ts — SEDIMENTARY ROCK (LOWER TERTIARY)—Sandstone and siltstone

TKgr — GRANITIC ROCK (TERTIARY AND CRETACEOUS?)—Commonly foliated granitic rock and gneiss, undifferentiated. Includes Monte Cristo, Ionitic, granodiorite, and minor diorite

Pzgd — GRANITIC AND METAGRANITIC ROCK (TRIASSIC)—Commonly foliated and heterogeneous chlorite-, biotite-, and hornblende-bearing quartz diorite, metagabbro, and diorite, and gneiss or other metamorphic rock formed by regional metamorphism of originally plutonic rock

pTgr — GRANITIC ROCK (PRE-TERTIARY)—Granitic rock, commonly foliated and heterogeneously mixed with gneiss. Undifferentiated

pTga — GABBRO (PRE-TERTIARY)—Locally pyroxene-bearing hornblende gabbro, commonly layered or foliated

pTgn — GNEISS (PRE-TERTIARY)—Undifferentiated gneiss

pTgnh — GNEISS (PRE-TERTIARY)—Generally homogeneous biotite- and hornblende-bearing gneiss and foliated granitic rock of quartz diorite, tonalitic, and granodioritic composition, minor interlayers of schist. Includes hornblende-bearing rock of Sulphur Mountain

pTgnm — GNEISS (PRE-TERTIARY)—Migmatitic paragneiss and orthogneiss heterogeneously mixed with commonly abundant schist

pTsc — SCHIST (PRE-TERTIARY)—Biotite- and hornblende-bearing schist and amphibolite. Commonly contains garnet, and, locally, chloritic, staurolitic, kyanitic, and sillimanitic. In places mixed with foliated granitic rock

pTga — GREENSCHIST (PRE-TERTIARY)—Low-grade metamorphic rock, including greenschist, blueschist, phyllite, and other metasedimentary rock

pTmb — MARBLE (PRE-TERTIARY)—Includes calc-silicate rock

pTum — ULTRAMAFIC ROCK (PRE-TERTIARY)—Peridotite, metaperidotite, serpentinite, and talc schist

CONTACT—Queried where uncertain, dotted where concealed

FAULT—Queried where uncertain, dotted where concealed, dashed where approximately located

STUDIES RELATED TO WILDERNESS

The Wilderness Act (Public Law 88-577, September 3, 1964) and related acts require the U.S. Geological Survey and the U.S. Bureau of Mines to survey certain areas on Federal lands to determine their mineral resource potential. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a geophysical survey of the Glacier Peak Wilderness (RF031) in the Mount Baker-Snoqualmie and Wenatchee National Forests, Chelan, Skagit, and Snohomish Counties, Wash. The Glacier Peak Wilderness was established by Public Law 88-577, September 3, 1964. The study area also includes eight areas classified as proposed wilderness (06031A, B, and C) during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979, and one area (06031C) proposed as an administrative addition.

INTRODUCTION

Location, access, and geographic setting

The Glacier Peak Wilderness encompasses 464,741 acres, including 483 acres of patented mining and millsite claims. Also included in the present study are nine areas adjoining the wilderness (see fig. 1), totaling 90,034 acres of recommended wilderness additions. All these lands are here collectively called the "study area." Access to the study area is provided by generally well maintained logging roads, gravel or dirt roads along major valleys, and foot trails. Roads extend up the Suiattle River, Trinity, and Lake Chelan–Stehekin. Other than the main access trails across a few passes (Cloudy Pass, Buck Creek Pass, Suiattle Pass, and Indian Pass), trails are rough, infrequently maintained, or nonexistent.

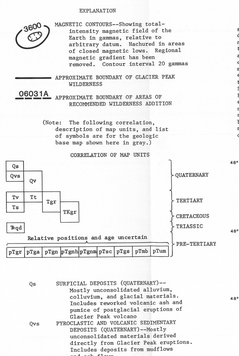


Figure 2.—Map of the Glacier Peak Wilderness and vicinity, showing interpreted magnetic provinces.

MAGNETIC PROVINCES

The characteristics of the magnetic patterns suggest subdivision of the study area into three distinctive magnetic provinces (fig. 2): (1) a northwest province characterized by northwest-trending, strongly lenticular or linear magnetic highs and lows and steep magnetic gradients; (2) a broad central province characterized by generally low magnetic relief and broken by subcircular to elliptical positive anomalies and by three conspicuous transverse magnetic belts, one from Mount Buckindy to Sonny Boy Creek, the second from Glacier Peak to near Bonanza Peak, and the third (as seen conspicuously, extending from Wenatchee Ridge on the southwest to near Garland Peak, in the Entiat Mountains to the northeast); and (3) a southwest province characterized by a highly complex group of subcircular to elliptical magnetic highs and lows showing little preferred orientation.

The magnetic highs in some of these areas may in part reflect concentrations of secondary magnetite and sulfides (if pyrrhotite is present), but mineralogy of the rocks has not been determined.

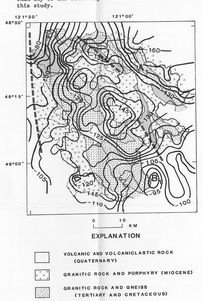
The aeromagnetic map suggests that most other granitoid bodies are much less magnetic than are the Buckindy and Cloudy Pass plutons, except for the Sloan Creek pluton in the west-central part of the study area. The only two plutonic bodies of low magnetic susceptibility for which data are available (see table 1) are the foliated pyroxene-biotite tonalite Sulphur Mountain pluton, which has susceptibilities averaging 5.7×10^{-3} (cgs units), and the foliated biotite tonalite Jordan Lakes pluton, which has susceptibilities averaging as much as even lower 4.3×10^{-3} (cgs units). Despite the significant magnetic gradients near the contact between the Cloudy Pass and Sulphur Mountain plutons obviously reflect their great difference in determined susceptibilities.

Units of generally homogeneous gneiss. The three major units of gneiss, the Swakane Biotite Gneiss, the Skagit Gneiss of Misch (1966), and a large unit of mostly biotite tonalitic gneiss of the Bench Lake area, east of Mount Buckindy, all have weakly susceptibilities close to 5.0×10^{-5} (cgs units) and uniformly show very low magnetic expressions. These magnetic characteristics account for their lack of magnetic imprint on the aeromagnetic map. The Magic Mountain Gneiss of Misch (1966) is associated with a pronounced positive magnetic anomaly. Its mean magnetic susceptibilities (average 9.5×10^{-4}, using cgs units) are lower than, but have about the same range of variation as, the Buckindy pluton to the southwest.

Schist units. Major schist units, mainly in the central magnetic province, include the Chiwaukum Schist, the schist of Nepesqua River, and the schist of Green Mountain. Although no susceptibility measurements were made on samples from these schist units, their very weak imprint on the aeromagnetic map suggests that they have very low magnetic susceptibilities, probably on the same order of magnitude as the three major gneiss units just discussed.

BOUGUER GRAVITY

Contoured bouguer gravity data are shown on a very simplified geologic sketch map (after Ford, written commun., 1983) of the Glacier Peak Wilderness and adjacent areas (fig. 3). The density of gravity stations is not great enough to allow correlation with individual plutons or lithologic units, as is possible using the magnetic data. Density measurements (table 1) for the major rock units suggest that many of the granitic plutons are nearly the same density; for instance, Buckindy, Sulphur Mountain, and Jordan Lakes plutons and all of the gneiss units vary less than 0.04 gm/cm³. The small standard deviation of all of the suites of samples from the above rock units (less than 0.03 gm/cm³) suggests that the densities of these units are fairly homogeneous. Mount Chaval and Middle Peaks, the two largest mafic plutons, have greater densities (2.84 gm/cm³ and 2.89 gm/cm³, respectively) than any of the other major rock units measured in this study.



EXPLANATION

- VOLCANIC AND VOLCANICLASTIC ROCK (QUATERNARY?)
- GRANITIC ROCK AND PORPHYRY (MIOCENE)
- GRANITIC ROCK AND GNEISS (TERTIARY AND CRETACEOUS)
- FOLIATED DIORITE AND GABBRO (PRE-TERTIARY)
- SCHIST (PRE-TERTIARY)
- GNEISS (PRE-TERTIARY)
- APPROXIMATE BOUNDARY, WILDERNESS
- APPROXIMATE BOUNDARY, PROPOSED ADDITION
- GEOLOGIC CONTACT
- FAULT
- BOUGUER GRAVITY CONTOURS — Contour interval 5 mgal; hachured in areas of closed lows

Figure 3.—Geologic sketch map (after A. B. Ford, written commun., 1983) of the Glacier Peak Wilderness and vicinity, showing generalized geology; contours are Bouguer gravity values.

The most prominent feature, in the center of the Bouguer gravity map, is a broad, irregularly shaped gravity low of about 20 mgal relief, one lobe of which is centered over the Quaternary volcanics and volcaniclastic rocks of Glacier Peak. Another lobe of the same gravity low is centered over the southeastern part of the Cloudy Pass pluton (unit Tmg, fig. 3). Although density determinations were not made, the volcanic flows and clastic rocks of Glacier Peak would be expected to be low in density and would, thus, produce a gravity low. However, the southeastern part of the Cloudy Pass pluton, over which the other lobe of the gravity low is centered, is of average density (2.77 gm/cm³ and would not be expected to contribute to a gravity low. This is also true of the part of the gravity low to pluton suggests that the pluton in this area is likely to be thicker or less dense rocks at depth. An alternative explanation would be that the Cloudy Pass pluton in this area has undergone significant alteration either by faulting and fracturing or by chemical and hydrothermal action or both, which has lowered its density.

Table 1.—Rock properties measurements

Rock Unit	No. Samples	Density (gm/cm³)			Susceptibility (cgs units)		
		Range	Mean	Standard deviation	Range	Mean	Standard Deviation
Gneiss of Bench Lake ----	7	2.61–2.73	2.67	0.04	6.0×10^{-5}–1.4×10^{-3}	3.8×10^{-4}	2.1×10^{-4}
Buckindy pluton ----------	9	2.60–2.72	2.68	0.03	5.3×10^{-5}–2.6×10^{-3}	1.7×10^{-3}	1.1×10^{-3}
Cascade Pass pluton ------	2	2.66–2.70	2.68	0.03	6.8×10^{-5}–1.3×10^{-3}	2.4×10^{-3}	3.3×10^{-3}
Cloudy Pass pluton -------	23	2.61–2.77	2.72	0.04	1.0×10^{-5}–2.4×10^{-3}	1.0×10^{-3}	8.0×10^{-4}
Jordan Lakes pluton ------	6	2.61–2.68	2.64	0.03	1.3×10^{-5}–6.8×10^{-5}	4.3×10^{-5}	1.9×10^{-5}
Chaval pluton ------------	14	2.69–2.99	2.86	0.07	1.5×10^{-5}–3.6×10^{-3}	3.4×10^{-3}	9.4×10^{-4}
Middle Peaks pluton ------	23	2.72–3.02	2.89	0.09	2.4×10^{-5}–2.0×10^{-2}	6.0×10^{-3}	5.3×10^{-3}
Skagit Gneiss ------------	10	2.64–2.73	2.66	0.03	5.2×10^{-5}–1.3×10^{-5}	5.0×10^{-4}	1.4×10^{-4}
Sulphur Mtn. pluton ------	10	2.62–2.69	2.64	0.02	1.7×10^{-5}–2.3×10^{-3}	5.7×10^{-4}	1.6×10^{-3}
Swakane Biotite Gneiss ---	4	2.64–2.67	2.65	0.01	4.3×10^{-5}–1.1×10^{-5}	5.2×10^{-5}	1.3×10^{-5}
Marblemount Meta-quartz Diorite.	15	2.72–3.02	2.84	0.08	4.4×10^{-4}–1.7×10^{-3}	3.4×10^{-4}	2.0×10^{-4}
Dumbell Mountain pluton-	14	2.64–2.87	2.75	0.07	7.1×10^{-4}–3.5×10^{-3}	9.0×10^{-4}	1.4×10^{-3}
Magic Mountain Gneiss ----	9	2.64–2.73	2.67	0.03	1.2×10^{-4}–3.5×10^{-3}	9.5×10^{-4}	1.1×10^{-3}

In the northeastern part of the study area (fig. 3), steep gravity gradients (marked A,) dip to the northeast and generally define the northwest-trending structural fabric of major rock units such as the Railroad Creek pluton and the Skagit Gneiss. This northwest-trending gradient cannot everywhere be so easily related to known geologic features and may be reflecting deep crustal features not evident at the surface.

In the southeast corner of the study area (fig. 3), a 15-mgal gravity high (B,) overlies the Chiwaukum Schist and overlaps into the northern part of the Tenpeak pluton. A positive magnetic anomaly is also present (see discussion M-16, Flanigan and others, 1983), and it appears likely that the gravity high is reflecting a very dense ultramafic rock in the foliated tonalite of the Tenpeak pluton and extending into the Chiwaukum Schist.

GEOPHYSICAL ANOMALIES AND MINERALIZATION

Porphyry-copper deposits are the predominant mineral deposits in the northern Cascade Range. The porphyry-copper province extends southward from the Canadian porphyry-copper belt. Mineral deposition is in many places controlled by northwest- to east-west-trending structures oriented approximately normal to the regional northeast-trending patterns of bedrock structures (Grant, 1969, 1982). The two best defined of Grant's (1969, fig. 12) transverse structural belts, the Glacier Peak belt and the Buckindy belt, cross the Glacier Peak Wilderness and the central magnetic province, where the belts are well marked by transverse magnetic features, and, to a lesser extent, by gravity highs and lows.

Many of the known mineral deposits, occurrences, and prospects described by Grant (1982) and by Bostelmeyer and Stoltzfus (1982) show a spatial relation to distinctive magnetic features that may provide valuable exploration guides and criteria for evaluating the study area's mineral potential. The spatial relationships of mineralized areas to magnetic anomalies fall generally into three classes: (1) those related to northwest-trending linear magnetic patterns or magnetic lineaments; (2) those related to northeast-trending and east-west-trending magnetic lineaments; and (3) those related to positive magnetic highs or flanks of magnetic highs. Details of these spatial relationships are given by Flanigan and others (1983). It should be noted, however, that some, including the possibly significant Royal development mine, near Trinity, show little apparent spatial relationship to the geophysical features.

Grant (1982) suggests that proportions of host rock in the Monte Cristo stock, a major element of the study area, by fracturing or faulting prior to mineralization, were the principal factor controlling subsequent mineral deposition and that intersections of northeast- and northwest-trending fracture systems provided an optimum environment for deposition. Several examples of such intersections are present within or adjacent to the study area and are reflected in the magnetic map. Strong northeast-trending magnetic linears are disturbed and displaced by a magnetic low extending eastward from near the Suiattle River prospect (Grant, 1982), north of Glacier Peak. The position of the Holden mine at the intersection of the above magnetic features possibly reflects fracture structures that may have controlled Holden mineralization. Many of the prospects in the Glacier Peak transverse structural belt of Grant (1969) are clustered about the eastward-trending magnetic low clustered about the eastward-trending magnetic low mentioned above; for example, the Kingfisher, Glacier Peak prospect, the Deer Fly prospect, the Iron Point mine, the Forrest Creek prospect, Copper Point prospect, and the Perseverance prospect of Stoltzfus and others (1982), east of the Holden mine.

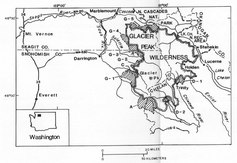
Except for several prospects and properties in the Buckindy transverse structural belt, and those already mentioned in the Glacier Peak belt, nearly all of the other known areas of significant mineralized rock (Grant, 1982; Bostelmeyer and others, 1982) are concentrated in the northeast magnetic province.

SUMMARY

On the basis of geophysical data, particularly the magnetic data, the Glacier Peak Wilderness and vicinity can be broadly divided into three parts. A large province northeast of Glacier Peak is characterized by signatures, northwest-trending magnetic lineaments, highs, and lows that can be closely related spatially to lithologic and structural features thought to be the sources of the geophysical responses. A central province characterized by a broad magnetic low, or trough, cut by two prominent transverse belts of magnetic highs and lows is thought to be related to Grant's (1969) transverse structural belts. A southwest province is marked by complex anomaly patterns associated with Tertiary plutons and volcanic rocks west of the Straight Creek fault.

Single low-amplitude, circular magnetic anomalies may reflect small bodies of rock perhaps not exposed in some places. Several subcircular anomalies in the central magnetic province are clearly associated with ultramafic bodies, the largest of which is near Twin Lakes, in the southern part of the study area, and is marked by a gravity high as well as a magnetic high.

The magnetic data also show features that relate to areas of known mineralized rock, and therefore the data may be useful guides for general mineral appraisal or for future exploration. Many mineral occurrences are spatially related to northeast- and east-west-trending magnetic belts and lineaments and to flanks of magnetic highs.



EXPLANATION

- Boundary of wilderness
- Areas recommended for addition to wilderness

Figure 1.—Index map showing location of the Glacier Peak Wilderness and adjacent areas. Areas recommended for addition to the Glacier Peak Wilderness are designated by letters: A, area 06031A; C, area 06031C; D, two areas making up addition 06031D; and G, five areas making up addition 06031G.

Present and previous studies

Magnetic data collected by airborne survey specifically for the Glacier Peak Wilderness study and entering aeromagnetic data were compiled to produce the aeromagnetic map shown here. Details of the airborne surveys used in this compilation, accompanied by a detailed geologic interpretation relating the magnetic data to specific geologic features, are given by Flanigan and others (1983). This qualitative study of the aeromagnetic data was undertaken to relate the many magnetic anomalies to geologic sources and to determine relationships, if any, that might be indicators of mineral potential.

Gravity was measured at many of the accessible points for which the topographic elevation had previously been established. Details of the gravity data collection, reduction, and pertinent facts are given by Sherrard and Flanigan (1983).

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