DEPARTMENT OF INTERIOR

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Preliminary geologic interpretation of the aeromagnetic map of the Colville Indian Reservation, Washington

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and nomenclature.

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Introduction

The Colville Indian Reservation is in north central Washington (Fig. 1) and lies within Okanogan and Ferry Counties. The reservation is about 75 miles long in an east-west direction and about 45 miles at its widest north-south direction. It is bounded on the east and south by the Franklin Roosevelt Reservoir and the Columbia River and on the west by the Okanogan River. The north boundary of the reservation is about 2 km south of the N48°30' parallel. Several state highways, secondary roads and many logging roads and trails provide excellent access on the reservation.

Geologic control for these interpretations has been based on early reconnaissance mapping on the Reservation. Current geologic mapping has been used in those areas where the data are available in preliminary form. These interpretations are preliminary and are subject to revisions as the geologic mapping is completed. This report presents a compilation and interpretation of aeromagnetic data that covers the reservation (pl. 1). The data represents parts of three aeromagnetic surveys flown in north-central Washington between 1973 and 1980 (fig. 1). The flight altitude for these surveys was 7,000 feet barometric. Line spacing was 0.5 and 1.0 mi as indicated by flight line location ticks on the contour map (pl 1). A regional field (IGRF updated to survey date) was removed from the data. The authors adjusted the base values so that the data are consistent between the three separate surveys.

This report was prepared by the U.S. Geological Survey for the Bureau of Indian Affairs in an effort to better understand the regional geology and the mineral potential of the Colville Indian Reservation.

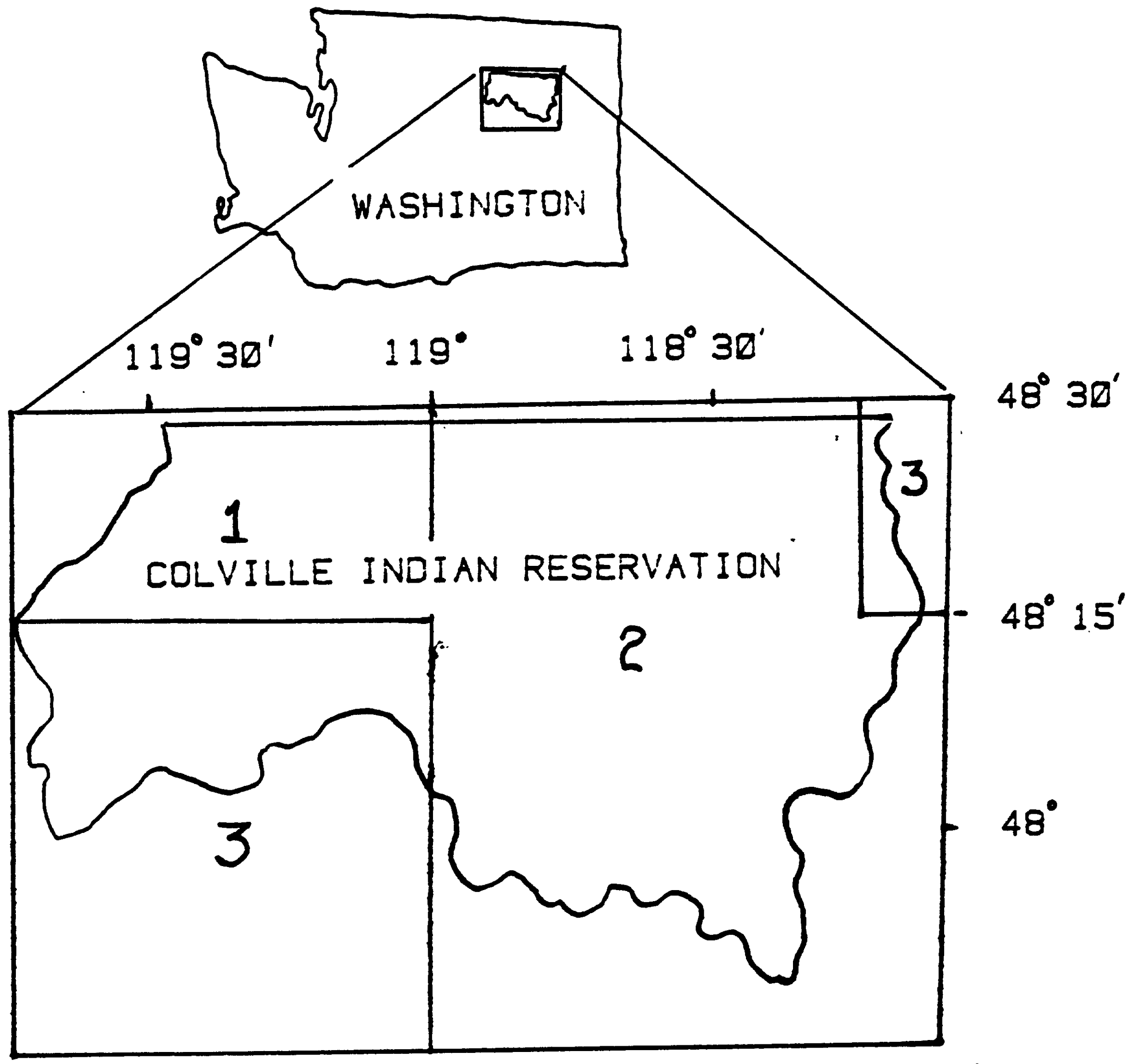

Figure 1. Index map of the State of Washington showing the location of the Colville Indian Reservation (inset), also shown are the location of three aeromagnetic surveys used to compile the composite aeromagnetic map. Data Sources: 1) USGS, (1977); 2) USGS, (1974), 3) USGS, 1982.

Factors concerning aeromagnetic interpretations

For ease of discussion of the relationship of the many magnetic anomalies to geologic features, an illustration has been prepared (pl. 2) which shows the approximate boundaries of individual magnetic anomalies and anomaly patterns. The locations of many of the mines and prospects as well as the approximate location of geochemical anomalies as determined by the Tribal Geology group (Erickson, written communication, 1982) are shown in order to illustrate the relationship of mineralization to magnetic features.

A study of the magnetic anomaly characteristics suggest that many of the magnetic anomalies or characteristic anomaly patterns can be related to geologic features. The amplitude and wave length of the magnetic anomalies are usually sufficiently different for the different major rock types that the areal extent of the source rock of magnetic anomalies can be recognized, especially where rock types of widely contrasting magnetic character are in contact. Interpretive boundary lines drawn through the area of steepest magnetic gradient of the magnetic anomaly generally define the boundary of the geologic source of the anomaly. Differences in the interpretive boundary and mapped geologic contacts can occur in areas where: 1. there is little or no contrast between the magnetic character of two rock units which are in contact; 2. the source of the magnetic anomaly is buried, or dips beneath overlying strata, or 3. the geology is complex such as a intrusive granitic mass interfingering with country rock, or where the intrusive body contains remanents of the intruded country rock which retain some of their original magnetic properties. Minor flexures in the magnetic contours and small (20-50 gamma) magnetic highs and lows may represent small plugs, dike swarms, intrabasement structures or local changes of magnetite content related to different phases of an intrusion. Local magnetic lows may be indicative of zones of low magnetite content or areas where the magnetic minerals have been altered by hydrothermal fluids or by major faulting. Alternatively, magnetic lows may represent reverse remanent magnetism, that is, magnetism acquired during a period in which the earth's magnetic field was reversed compared to present polarity. Major faulting may also be seen in the magnetic contour map (pl 1) as lineaments defined by alinement of zones of high magnetic gradient.

Some topographic effects are reflected in the data especially in the areas of rugged topography. In normally polarized magnetic terrane the proximity of a topographic high may cause a magnetic high to be recorded as the survey aircraft flies over it. Conversely, when the aircraft flies over a deep valley a magnetic low may be recorded. Such terrain-induced anomalies are not a serious concern in the present data except in two cases discussed later.

The interpretive map (pl. 2) shows boundaries outlining both individual magnetic anomalies and magnetic patterns comprised of multiple magnetic anomalies. The "M" within the boundary of a magnetic anomaly signifies that the unit is more magnetic than surrounding rocks, "L" means that the anomaly is less magnetic. The subscript number with the M and L is for identification in the text discussion. Magnetic lineaments identified from the alignment of magnetic gradients or magnetic lows are indicated by a broken bar symbol.

Setting for the Colville Indian Reservation

The Colville Indian Reservation lies at the southern end of the Omineca crystalline belt of southeastern British Columbia (Monger and Price, 1979) and is bounded on the east by the Kootenary and the Purcell Trench, and on the west by the intermontain belt. According to Rinehart and others (1975) the oldest recognized rocks are deformed metamorphosed sedimentary rocks (Covada Group) of early to late Paleozoic age. These rocks have been extensively intruded by a wide variety of late Mesozoic to early Tertiary granitoid rocks which occupy a large percentage of the reservation. Tertiary volcanic rocks overly the granitoid rocks in many places, most notable is a north-northeastern trending belt filling the Republic Graben and a north-south belt along the San Poil River Valley, in the Keller Graben.

In a regional study of potential field geophysical data (gravity and magnetics) of the gneiss terrane of northern Washington and southern British Columbia, Cady and Fox (1983) indicate that the Omineca Crystalline Belt is characterized by a broad regional gravity high marked by local gravity highs associated with individual gneiss domes. While, the latter part of the above statement may indeed be true in broad regional terms, detail gravity data presented by Sherrard and Flanigan (1986) suggest that the Kettle gneiss dome may be a notable exception. Whereas, the Okanogan gneiss dome does show a local gravity high of about 20 mgal, the Kettle gneiss dome is characterized by a 10-12 mgal low. Cady and Fox also suggested that the Omineca crystalline belt is characterized by regional low aeromagnetic relief and that locally hornblende-biotite granites often cause magnetic highs whereas biotite-muscovite granites produce generally weak magnetic relief. Our data confirm this latter conclusion in several areas on the reservation, most notably, an area of the Kettle gneiss dome where a biotite-muscovite granitic-gneiss (unit "gg" of Fox, 1982, unpublished map) is cut by a moderately magnetic hornblende-biotite granite (see discussion of anomaly M_{13}).

There are several lines of evidence in the magnetic data, which are also supported by gravity data, suggesting that regional graben structures extend southward beyond the reservation into at least the northern part of the Columbia Plateau. For instance, a broad, south to southwest trending magnetic low (L9) suggest continuity of the Republic Graben into the Columbia Plateau well beyond its mapped termination. A 20-mgal gravity low, although much broader, coincides with the magnetic low thought to be the expression of the Republic Graben extending into the Columbia Plateau (see Sherrard and Flanigan, 1986). The same is true, to a lesser extent, of the Keller Graben.

Magnetic Provinces

The characteristics of the magnetic data of the Colville Indian Reservation (plate 1) suggest subdividing the area into three distinct magnetic provindes (fig. 2): (1) the Eastern magnetic province, characterized by broad low- to- moderate magnetic relief which is, in general, about 100 gammas lower than in the central magnetic province; this province is conspicuously bisected by a general east-west magnetic high; (2) a Central magnetic province characterized by northeast trending magnetic highs and lows (ridges and valleys), low amplitude subcircular highs and lows and moderate to steep northeast trending linear magnetic gradients; and (3) the Western magnetic province dominated by a single broad subcircular magnetic anomaly associated with the rocks of the Okanogan gneiss Dome.

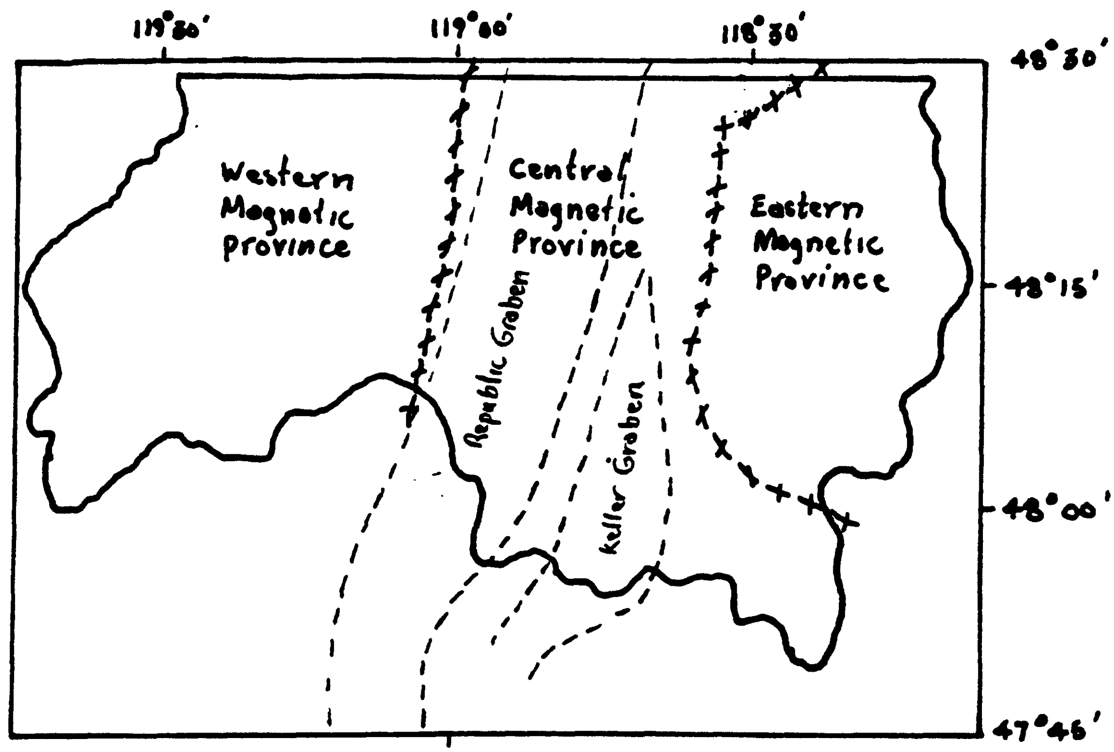

Figure 2. Sketch of the Colville Indian Reservation showing the subdivision of the area into magnetic provinces based on common magnetic characteristics.

Selected Geologic Features and their Imprint on the Aeromagnetic Map

Metasedimentary rocks. The oldest rocks in the study area, thought to be of Permian age (Muessig, 1967) are the Covada Group (Pardee, 1918) consisting of phyllite, quartzite graywacke, shale, limestone, and mica schist (Staatz, 1964) in the Bald Knob quadrangle. Further north near the town of Republic, the Covada Group includes chert, conglomerate, and marble (Muessig, 1967). In the Eastern magnetic province the Covada Group is most extensive; it has been widely intruded there by large igneous bodies, and has strong imprint on the magnetic map (L_{13}, L_{14}). These metasedimentary rocks are distinguished by low magnetization. A limited number of samples tested from the Covada Group indicate that the average susceptibility is 0.0001 cgs units (table 1). In the central magnetic province, metasedimentary rocks of the Covada Group generally decrease in abundance from north to south with their strongest influence on the magnetic map, being at L_4, in the north-central part of the Bald Knob quadrangle. Influence of the metasediments in the magnetic map decreases to the southwest. In the western magnetic province few Covada Group rocks have been identified, having been assimilated nearly completely into the plutonic rocks that intruded them, thus, there are few if any areas where local magnetic lows can be attributed to these metasedimentary rocks.

Plutonic granitoid rocks. Massive intrusive rocks of Cretaceous and Tertiary age, ranging in composition from quartz monzonite to quartz diorite (Staatz, 1976) dominate the geology of the central and western magnetic provinces. The magnetic susceptibility of these rocks appear to range from very low to moderately high; for instance, with quartz porphyry of Utterback (1980, unpublished map) causing a magnetic low (anomaly L_7), and granitoid rocks to the southeast causing a magnetic high (M_{11}). Other granitoid rocks can bedistinguished by anomalies of lesser contrast than those just discussed; for instance, anomalies M_7 and M_8 caused by hornblende-biotite granodiorite and the garnetiferous leuco-granite of Carlson and Peters (1982, unpublished map), are in clear, but lesser contrast to anomaly L_{10} caused by porphyritic granodiorite of Atwater (1983, unpublished map). Only a few susceptibility measurements have been made on these plutonic granitoid rocks and it is obvious that much more work needs to be done in this area; for instance the magnetic signature of plutonic rocks hosting the Mount Tolman moly-copper porphyry deposit may be a valid guide to other areas on the reservation where similar mineralization occurs.

Volcanic rocks. The northern half of the central magnetic province is dominated by the imprint of Sanpoil volcanic rocks of moderate to high magnetization. Susceptibility measurements were made on samples taken along a roughly east-west profile extending from just east of the Sherman fault where it crosses the Twenty-three Creek road on the Seventeenmile Mountain quadrangle, to near Strawberry Mountain in the Bald Knob quadrangle. Major flow rocks range from dacite to andesitic composition going from east to west (F. Moye, written commun., 1982). Andesitic rocks exhibit somewhat lower magnetic susceptibility than do the dacite flows to the east (0.0015 compared to 0.003 cgs units, table 1), which correlates well with observations by Staatz (1964), (see earlier discussion of anomaly L_3). Sanpoil volcanic rocks along the Sanpoil River in the Keller quadrangle have little reflection in the

Table 1. Summary of rock properties measurements, Colville Indian Reservation

Rock type	number of samples	Wet density g/cm^3	Standard deviation g/cm^3	Suscep-tibility cgs units	SD
Sanpoil dacite	9	2.62	0.068	.003	0.003
Sanpoil andesite	13	2.46	0.088	0.0015	0.001
Scatter Creek rhyodacite	2	2.42	0.175	0.0013	0.0011
Scatter Creek rhyolite	2	2.64	0.040	0.0023	
Covada group-metasedimentary rock	12	2.68	0.090	0.0001	0.0002
Quartz monzonite	6	2.67	0.216	0.0006	0.0003
Diorite - granodiorite	6	2.78	0.055	0.002	0.0009
Biotite porphyry (Hypabyssal)	9	2.58	0.036	0.0026	0.0009
O'Brien Creek (?) Crystal tuff	2	2.29	0.072	0.0006	0.0002

magnetic data, except in the area of anomaly M_6. The reason for this may be twofold: (1) the flows are relatively thin as compared to their equivalent rocks in the Republic Graben and thus contribute less to a composite magnetic anomaly; (2) the anomalies from the flow rocks are obscured by the magnetic anomaly associated with their intrusive equivalent--porphyritic hypabyssal dikes and dike swarms that have extensively intruded country rock to the east (Atwater and McGroder, 1982, unpublished map).

Columbia Plateau volcanic rocks occurring mostly in the southern parts of the central and western magnetic provinces have little expression in the magnetic map, most probably due their limited areal extent and thickness. One area located in the Western magnetic province (anomaly M_2) is an exception.

Major fault structures. Bounding faults of the north-northeast-trending Republic graben which extend into the study area from near the Canadian border (Staatz, 1964, Staatz and Morris, 1976) are well marked in some places by linear magnetic gradients, but are less distinctly marked in other places. For instance, the Sherman fault a major east boundary fault, can be traced quite clearly by magnetics from the northeast to about the middle of the Nespelem quadrangle, and then somewhat less clearly to the southwest. Likewise, the west boundary faults, the Long Lake, King Creek and Nespelem River faults, (Staatz, 1964) are fairly evident in the magnetics where they cross the Bald Knob quadrangle, but less evident over granitic rocks to the southwest.

Parallel faults farther to the east which may bound the Keller Graben are clearly reflected in the magnetic map. Manila Pass fault can be traced quite clearly from south of the Nespelem quadrangle, where it crosses the southeast corner, to beyond the northwest corner of the Keller quadrangle. Likewise, the Shamrock Fault mapped discontinuously in surface geology through the center of the Keller quadrangle (Atwater and McGroder, 1983, unpublished map) can be traced by linear magnetic gradients both to the north and south for several tens of kilometers. Of equally clear expression, are north-south magnetic linear gradients, four to five kilometers east of the Shamrock Fault in the Keller quadrangle, which may be related, in part at least, to a fault zone postulated by Atwater and McGroder in the southeast corner of the Keller quadrangle.

Northwest trending faults are not strongly reflected in the aeromagnetic map, except for the linear magnetic feature south of Omak Lake previously mentioned (see anomaly M_1 discussion).

Magnetic Features and Potential Mineralization

Aeromagnetic data is routinely used by the U.S. Geological Survey in mineral assessment programs because it has proven to be a useful tool in aiding geologic mapping. It is especially helpful in delineating fault structures that may have been important mineral emplacement controls, as well as in indicating possible buried intrusive bodies that might have been sources for mineral deposition. Other equally important relationships have been noted in mineral assessment studies, such as the spatial relationship of known deposits, prospects and/or mines to magnetic features. Enrichment of magnetite in biotite-muscovite granitic rocks causing magnetic highs may be indictive of source rocks for possible uranium deposits as suggested by Cady and Fox (1983).

In an effort to illustrate some of the spatial relationships of mineral deposits to the magnetic features previously discussed, geochemical stream sediment and soil sampling anomalies (Robbins, 1971, and Salisbury and Dietz, Inc., 1980, unpublished report) have been added to plate 2. In addition, some of the many mines, and mineral prospects on the reservation are also indicated on plate 2 (Rinehart and others, 1975).

Nearly all of the previous mining activity took place in the central and eastern magnetic provinces. Many of the mines, prospects and geochemical anomalies within these two magnetic provinces appear to be spatially related to areas of granitoid rock of low magnetization, the most prominent associations being: anomaly L_7 and the Mt. Tolman deposit, anomaly L_{10} and the Nespelem District, and anomaly L_5 and the Park City District. The areas of these three anomalies are in large part covered by alluvium, glacial drift, and volcanic rocks, but these areas should be considered prime exploration targets for buried mineralization. A preliminary interpretation of aeromagnetic data obtained specifically for company exploration in the central magnetic province, Roth and Papazian (1978, unpublished report), identifies granitic rock of low magnetization (labelling them type 1 granitoid rocks) and suggests that areas containing those rocks and meeting other criteria, should be considered for further exploration on the reservation. The three magnetic lows (L_5, L_7, L_{10}) just discussed, generally, coincide with Roth and Papazian's type 1 granites.

Anomalies L_6, L_8, and L_{12} are over areas of weakly magnetized rocks which do not contain significant geochemical anomalies. They are less attractive mineral targets for this reason, but could contain mineralization more deeply buried.

Several relationships combine to suggest that the area outlined as anomaly L_4 (pl. 2) should have high priority for future exploration. Major faults and a similar sequence of lithologic units that are found in the Republic Mining District just to the north (Full and Grantham, 1968) make this area very attractive as an exploration target. The trend of anomaly L_4 reaches northward into the Republic Mining District; this aspect, and the presence of geochemical anomalies due to metallic minerals similar to those mined in the district add weight to mineral favorability for anomaly L_4.

In contrast, several geochemical anomalies appear to be spatially related to the outer boundary of moderately magnetized granitic rocks that intrude the Covada metasedimentary rocks in the Eastern magnetic province (M_{12}). One notable area lies along the contacts of the intrusive in the southeastern corner of the Seventeenmile Mountain and northeastern corner of the Keller quadrangles. A combined helicopter electromagnetic/magnetic survey of this area (Thirtymile Creek) indicated numerous geologic conductors, most likely related to carbonaceous rocks in the Covada Group (Flanigan and others, 1982). Pronounced local magnetic highs are thought to be related to ultramafic rocks and serpentinite. The Thirtymile Creek area is probably similar geologically to the Covada district on the eastern edge of anomaly M_{12}. Within the Covada district, recent geologic and geochemical investigations have led to the conclusion that the area holds a high potential for future mineral discoveries (Dansart, 1982). Our magnetic data suggest that granitic rocks thought to be the source of anomaly M_{12} extend eastward beneath the metasedimentary rocks of the Covada Group. Further, detail gravity measurements (Sherrard and

Flanigan, 1982) outline a local gravity high thought to reflect a shallow intrusive cupola in an area near Rattlesnake Mountain and Stranger Mountain. Such a body could have been the source of the many mineral shows in the district.

To the south, mostly in the Wilmont quadrangle, anomaly L_{14} is associated with many geochemical anomalies. Roth and Papazian (1979) suggest that this area of low magnetic relief reflects granitic rock under a relatively thin section of metasedimentary cover. Whether this is true or not cannot be ascertained from the magnetic data alone inasmuch as, the overall magnetic expression could be attributed to a thick section of weakly magnetized metasedimentary rocks. The proposed hypothesis of Roth and Papazian is attractive however, because it suggests possible sources for the many geochemical anomalies in the area.

A large uranium geochemical anomaly lies within Kettle gneiss dome rocks in the eastern part of the Seventeenmile Mountain and the western part of the Twin Lakes quadrangles. Specifically, the uranium anomaly is associated with biotite (muscovite) granitic gneiss (unit "gg" of Fox, 1983, unpublished map), which confirms Cady and Fox's (1983) conclusion that such granitic rocks can contain significant uranium and could therefore be the source for undiscovered uranium deposits in nearby suitable host rocks. Exploration criteria and other potential uranium-mineralized areas similar to the nearby Midnight and Sherwood uranium mines are given in Milne (1979).

Interpretation of aeromagnetic anomalies

Anomaly M_1. This anomaly in the northwest part of the reservation is a broad magnetic high of about 460 gamma. It is elongated in a north-south direction and extends northward outside of the reservation. The anomaly lies over layered paragneiss and mylonitic granodiorite gneiss of the Okanogan gneiss dome which is thought to be the magnetic source. Snook (1965) suggests that these Tonasket gneisses are a part of the large Colville batholith lying principally to the north. The anomaly is bounded on the west by the Okanogan River Valley which is conspicuously marked by a broad magnetic low (see discussion on anomaly L_1). On the east, major north-trending structures that control the western side of the Republic Graben (Staatz, 1964) generally terminate anomaly M_1. On the south, and particularly the southwest, the anomaly boundary is less clearly defined, especially where Tertiary volcanic flows (Columbia River basalt) overlie the granodiorite rock of the gneiss dome and produce separate anomalies. There is little evidence in the magnetic data of a northwest bounding fault suggested by Snook (1965) in the area of Omak Lake on the southwest edge of the dome. There is, however, some suggestion of a magnetic lineament trending northwest a few kilometers to the south of Omak Lake as shown on plate 2.

Anomaly M_2. This subcircular anomaly of slightly over 100 gamma overlies part of a large area mapped as Miocene Columbia River Basalts. Elsewhere on the map the flow rocks give a pronounced magnetic high. Anomaly M_2 is believed to reflect a substantially thicker section of basalt rock than occurs in other Columbia River basalt flows in the area.

Anomalies M_3, M_4, M_5 and M_6. These short-wavelength, subcircular, interwoven magnetic anomalies ranging in amplitude from 100 to over 300 gamma characterize the magnetic response of the Tertiary Sanpoil volcanic rocks (Staats, 1964, Moye, 1981, unpublished map) in the Republic Graben (anomalies M_3, M_4, and M_5) and in a north south belt (anomaly M_6) (Atwater and McGroder, 1982, unpublished map) along the Sanpoil River in the Keller quadrangle. Assuming a constant magnetic susceptibility for the Sanpoil volcanics the thickest section of volcanic rocks in the Republic Graben on the reservation is outlined by anomaly M_4. In figure 3 data from profile A-A' (pl. 2) is compared to the theoretical magnetic field calculated for three bodies placed along the profile. Parameters of the bodies were successively changed to produce the closest fit between the observed and calculated data. The central body represents the volcanic rock in the Graben, the bodies on either side were necessary to produce a reasonable fit. The assumed negative magnetic susceptibility (-0.001 cgs) would suggest that the bodies on either side of the Republic Graben may contain a significant component of reverse remanent magnetism although no remanent studies have been made by the authors to ascertain this fact. The volcanic rock along the profile based on these theoretical calculations, using a magnetic susceptibility contrast of 0.001 cgs units, is about 1,750 m (5,740 ft) thick in its thickest part. While, the configuration of the assumed model is approximately correct at the chosen susceptibility contrast, the body would need to be increased in thickness if the susceptibility contrast is less than 0.001 cgs units. Various estimates have been proposed for the total amount of subsidence within the Republic Graben, from 2,156 m (7,000 ft) by Staatz (1964) to 2,500 m (8,200 ft) by Soule (1975). Values determined for the graben's vertical displacement, and thus the thickness of the Sanpoil volcanics, would depend on the location of the profile under analysis, inasmuch as the displacement decreases northward and southward from a maximum in the center (north of the reservation). Also if there is a component of reverse remanent magnetism with the various flows of the Sanpoil Volcanics, these thickness estimates would represent a minimum.

Except for anomaly M_6 the Sanpoil volcanic rock mapped along the Sanpoil River valley east of Keller Ridge have little imprint on the magnetic map. The reason for this is most likely related to their relatively limited thickness as compared to the thickness of Sanpoil rocks within the area outlined as M_6 within the Republic Graben, although reverse remanent magnetism may be a factor as well.

Anomaly M_7. This elongated anomaly of approximately 60 gamma amplitude trends about N30°E in the southern one-half of the Nespelem quadrangle. It is parallel to the east boundary faults of the Republic Graben and is immediately west of the Sherman Fault (Carlson, 1983, unpublished map). Anomaly M_7 lieslargely over a garnetiferous leucogranite containing plagioclase, orthoclase, quartz, garnet and magnetite which is thought to be its source. The magnetic high extends southwest well beyond the southern reservation boundary and can be identified by small magnetic highs alined in the Barker Canyon quadrangle.

Anomalies M_8 and M_9. The two magnetic highs are part of a northeast trending magnetic ridge extending from the southeastern half of the Nespelem quadrangle to the northwestern corner of the Keller quadrangle. Anomaly M_8 is quite clearly related to equigranular biotite granodiorite and hornblende - biotite-diorite-granodiorite (Carlson, 1983, unpublished map) in the Nespelem quadrangle. Anomaly M_9 may be reflecting the magnetic character of porphyry hypabyssal intrusive rocks in the northwestern corner of the Keller quadrangle (Atwater and McGroder, 1983, unpublished map).

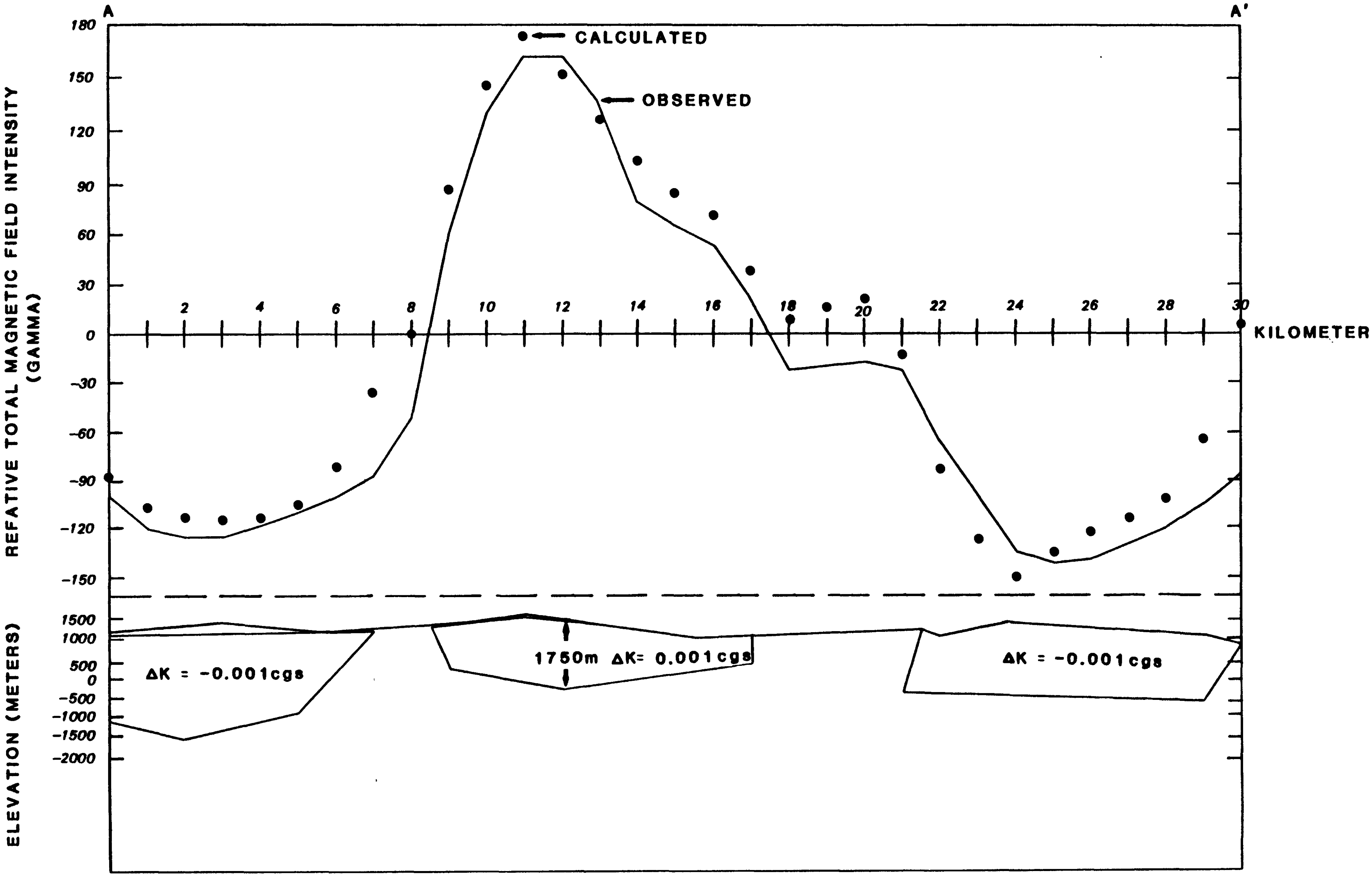

Figure 3. Magnetic profile across the volcanics filling the Republic graben showing the observed total intensity magnetic field (solid line) and the calculated magnetic field (·) from three bodies of contrasting susceptibility shown below. The Republic graben is represented by the central body.

Anomaly M_{10}. A north-south trending anomaly on the east of the Sanpoil River, M_{10}, forms a magnetic ridge of about 100 gamma amplitude. It lies over a wide variety of lithologies ranging from greenstone rocks, to talc-carbonate phyllitic rocks to porphyritic granodiorite rocks (Atwater and McGroder, 1982, unpublished map). These rocks have been intruded by swarms of dikes of porphyry hypabyssal rocks that exceed an estimated 10 percent of the country rock. The hypabyssal dikes and dike swarms are thought to be the source of the magnetic ridge (M_{10}) at least in the Keller quadrangle.

Anomaly M_{11}. This anomaly is an irregularly shaped magnetic feature exceeding 300 gamma in amplitude which lies just south of and possibly forms part of the magnetic ridge just discussed (anomaly M_{10}). It lies over porphyritic medium-grained granodiorite in the south central part of the Keller quadrangle (Atwater and McGroder, 1982, unpublished map) and over medium and coarse-grained, mainly leucocratic granitic rocks in the Wilbur, Lincoln and Wilmont Creek quadrangles, and it probably reflects these igneous rocks.

Anomaly M_{12}. This anomaly forms an east-west ridge that breaks two rather flat magnetic terranes (L_{13} and L_{14}) and lies over predominantly granitic rock in the northern half of the Wilmont Creek quadrangle. These granitic rocks are thought to be the source of the magnetic anomaly and probably have similar magnetite content as those causing anomaly M_{11} to the south.

Anomaly M_{13}. This anomaly of 300-400 gamma maximum amplitude correlates with hornblende - biotite granitic rocks cutting the northern part of the Kettle gneiss dome (Fox, 1983, personal commun.). The magnetic expression of these rocks is consistent with the observations of Cady and Fox (1983) who suggest that hornblende-biotite granites produce local magnetic highs in a regional magnetic pattern of low magnetic relief.

Anomaly L_1. Anomaly L_1 is a north-south trending, broad magnetic low of approximately 100 gammas located in the Okanogan and Bridgeport quadrangles on the northwest edge of the Reservation. The anomaly crosses at an oblique angle to the Okanogan River Valley, where the great depth to bedrock may be contributing to the general flat magnetic character. Further to the south the anomaly lies over granitoid Colville batholith rocks (Pardee, 1918). From the latter relationship, one may infer that this anomaly also defines a lobe of granite extending northward beyond the study area. These granitoid rocks produce anomalies that are distinctly lower in amplitude than many discussed previously. Other much smaller granitic bodies, as will be discussed, lie mainly in and near the central trough of the Republic Graben and may represent an unique magmatic phase of the intrusive history of the region.

Anomaly L_2. This roughly boot shaped anomaly is believed to be caused by gneissic and granitoid rocks (Atwater, 1983, unpublished map) in the Boot Mountain and Alameda Flat quadrangles. Similar rocks extend southward across the Columbia River and into the Leahy quadrangle, based on the trend of this distinct anomaly.

Anomaly L_3. A subcircular magnetic low of about 100 gamma intensity, L_3 is located mostly in the southeast corner of the Bald Knob quadrangle. It lies partly over granitic rocks identified in early mapping (Staats, 1964) which are distinctly different magnetically from the surrounding granitic rocks, and which may be genetically related to weakly magnetized granites discussed earlier (see anomaly L_1 discussion). The anomaly also partly overlies Sanpoil volcanics south of North Nanamkin Creek. Staats (1964) indicates that the Sanpoil volcanics in the Bald Knob quadrangle generally vary in composition from the northeast to the southwest. Rocks in the northeast contain more mafic phenocrysts than those in the southwest, where quartz phenocrysts predominate. The magnetic content of the volcanics seemingly follows a similar pattern, as evidenced from the magnetic map where larger magnetic highs, including M_4 are present in the northeast part of the quadrangle than are present in the southwest part.

Anomaly L_4. This magnetic low of more than 150 gammas located in the north-central part of the Bald Knob quadrangle lies mostly over metasedimentary rocks consisting of greenstone, phyllitic quartzite, phyllite and graywacke (Staatz, 1964). Major west bounding faults of the Republic Graben such as the King Creek, Long Lake and Nespelem River faults pass through the area of the magnetic low. Rock of moderate to high magnetic susceptibility lie to the east (Sanpoil volcanics) and quartz monzonite, quartz diorite and granodiorite rocks of unknown susceptibility occur to the west of anomaly L_4. The magnetic character of the metasedimentary rocks is clearly imprinted on the magnetic map as is the character of the extrusive rocks to the east and intrusive granitoid rocks to the west.

Anomaly L_5. This magnetic low of rather low amplitude (less than a few tens of gammas) is not clearly defined because of superimposed anomalies from magnetic rocks (Sanpoil volcanics?) to the southeast (M_5) and from granitoid rocks to the west and north (M_1). Anomaly L_5 lies largely over metasedimentary rocks consisting of black shale and schist, and flow rocks (Staatz, 1964), all presumably weakly magnetized west of the Nespelem River Fault.

Anomalies L_6, L_7 and L_8. These three magnetic lows form a north south magnetic valley parallel to the Republic Graben just east of Keller Ridge. They range in amplitude from near 100 gammas in the Mount Tolman area (L_7) to less than 40 gammas just north of Bridge Creek (L_8). Anomaly L_7, the largest of the three features, lies principally over porphyritic granodiorite (unit "pmg", Atwater and McGroder, 1983, unpublished map) in the Keller, Wilbur, and Grand Coulee Dam quadrangles. Rocks of similar magnetic properties apparently extend some 10 km in a southwest direction across the Columbia River into the Columbia Plateau as evidenced by magnetic anomaly L_{9a}. Anomalies L_6 and L_8 lie mostly over lava flows and pyroclastic rocks just east of the Sanpoil River in the Keller quadrangle (units "T_{sb}" and "T_{sl}", Atwater and McGroder, 1982, unpublished map). Except for magnetic highs M_6 and M_{10} the volcanic rocks show little imprint on the magnetic map. Therefore any magnetic expression in areas where volcanic rocks occur most likely reflects underlying porphyritic intrusive rocks (see discussion of magnetic high M_3 - M_6).

Anomaly L_{9a}. As mentioned above, anomaly L_{9a} appears to be a continuation of anomaly L_7 and probably reflects granitoid rock of similar magnetic properties to those mapped to the northeast by Utterback (1980, unpublished map) and Atwater and McGroder, 1983, unpublished map) to the northeast.

Anomaly L_{10}. This magnetic low, of less than 40 gammas, is located mostly in the west-central part of the Nespelem quadrangle over alluvium and glacial till. It extends into the adjacent Alameda Flat quadrangle where it overlies porphyritic granodioritic rocks (Atwater, 1983, unpublished map) that may be its source. The magnetic data suggest that the porphyry granodiorite are rocks that are less strongly magnetized than granotoid rocks to the west and are probably similar in magnetite content to those to the east at anomaly L_7.

Anomaly L_{11}. This subcircular magnetic low of about 30 gammas is located equally in the southwestern quadrant of the Nespelem quadrangle and the southeastern quadrant of the Alameda Flat quadrangle. The axis of the low approximately corresponds to the course of the Columbia River, and in part may reflect a thick section of deposits consisting of clay, sand, gravel and glacial till.

Anomaly L_{12}. L_{12} is an irregular shaped magnetic low of about 80 gammas in the east-central part of the Nespelem quadrangle. Detail mapping is not yet available in the area so one can only postulate the nature of the source rocks. Early geologic compilations (1:125,000) of the reservation suggest that Colville Batholith granitic rocks underly the low and most probably are similar in composition, particularly concerning magnetite, to the porphyritic granodiorite thought to be the source of magnetic low L_{10}.

Anomaly L_{13} and L_{14}. The eastern part of the reservation is dominated by a broad magnetic low of 100-200 gamma conspicuously cut by a east-west magnetic high (M_{12}). Both the northern part of the low, L_{13}, and the southern part, L_{14}, generally lie over metasedimentary rocks of the Covada Group (Pardee, 1918) and both lows are thought to be reflecting the normal weak magnetization of these metasedimentary rocks.

Anomaly L_{15}. This magnetic low lies mainly in the western part of the Twin Lakes quadrangle but extends well into the eastern half of the Seventeenmile Mountain quadrangle. Rocks exposed in this area form the principle part of the Kettle Gneiss Dome; they include biotite (muscovite) granite, granitic gneiss and protolithic rocks consisting of biotite schist, quartzite, marble and phyllites (Fox, 1983 and Holder, 1983, unpublished maps). The central part of the magnetic low (L_{15a}) coincides well with Fox's unit gg consisting of biotite (muscovite) granitic gneiss interlayed with quartzite and biotite schist.

Anomaly L_{16}. A magnetic low of about 200 gamma intensity, L_{16} extends southwest into the study area in the north central part of the Seventeenmile Mountain quadrangle. Quartz monzonite, quartz monzodiorite and microgranite rocks have been mapped in the area by Holder (1983, unpublished map of eastern half of Seventeenmile Mountain quadrangle), and are thought to be, in part a least, the source of the magnetic low. Major boundary faults, such as the Sherman fault, of the Republic graben pass through the area and may be contributing to the overall magnetic expression.

Conclusions

Based on this qualitative study of the aeromagnetic map of the Colville Indian Reservation, the following general and specific observations can be stated: 1) In the eastern magnetic province, as defined in this study, metasedimentary rocks along with weakly magnetized igneous rocks of the Kettle gneiss dome underlie a broad area of low magnetic relief. The area is bisected by an east-west ridge-like magnetic anomaly thought to be caused by granitic rocks slightly more strongly magnetized than adjacent rocks. Several geochemical anomalies and prospects seem to be spatially related to the periphery of the rocks causing the magnetic ridge, most notable are geochemical anomalies and prospects in the Covada district. Uranium-rich biotite (muscovite) granitic gneiss of the Kettle gneiss dome may be the source of undiscovered uranium deposits in nearby suitable host rocks. 2) In the Central magnetic province the aeromagnetic data strongly reflect north-northeast structures and lithologic grain. Subcircular to elongated magnetic anomalies of differing amplitudes suggest plutonic rocks of slightly different magnetite content; this in turn, suggests different magmatic phases for magma sources for the intrusive events. Many of the geochemical anomalies, prospects and mines in the Central magnetic province are related to igneous rocks that produce low magnetic relief. Areas thought to have high mineral potential are anomalies L_4, L_5, L_7, and L_{10}. 3) The Western magnetic province is dominated by a broad magnetic high associated with the Okanogan gneiss dome. Secondary, short wave length, low amplitude magnetic anomalies in the southwestern part of the province can be related to Columbia River basalt flows. Weakly magnetized granitoid rocks are present in the southeastern part of the Boot Mountain quadrangle (L_2) and may represent a possible host for porphyry moly-copper mineralization, such as found at Mount Tolman.

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