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AEROMAGNETIC AND GEOLOGIC MAP OF PART OF NORTHWESTERN MONTANA AND NORTHERN IDAHO

By

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INTRODUCTION

The area studied consists principally of Belt rocks that have been intruded by Precambrian gabbroic sills and by Mesozoic and Cenozoic plutons, sills, and dikes; most of these intrusives are intermediate to acidic in composition. Tertiary extrusive rocks are known in small parts of the area.

These rocks are exposed in several mountain ranges: from northeast to southwest, the Flathead Mountains, the Kootenai Mountains, the Cabinet Mountains, and the Coeur d'Alene and St. Joe Mountains of the Bitterroot Range. The Purcell Trench, which marks the eastern bounday of the Kootenai arc mobile belt, crosses the northwestern part of the area and the Rocky Mountain Trench crosses the northeastern part. (See index to physiographic names and mining districts.)

The famous Coeur d'Alene mining district, as well as several other districts that also have histories of sizeable silver-lead-zinc production, is located in the area. Among the other districts are the Lakeview, Clark Fork, and Talache mining areas of Idaho, and the Mineral County, Hog Heaven, Cabinet, Libby, Troy, and Blue Creek mining areas of Montana.

This map relates geology, aeromagnetic data, and lead isotope data to the vein-type mineralization of the area. Although the aeromagnetic data are complete, both the geologic and the isotopic studies are still in progress. Partly because of the preliminary nature of the geologic and lead isotope data, no quantitative analysis of the magnetic data has been undertaken. All data herein are being released in preliminary form before completion of the geologic and isotopic studies, which will take several more years of work, because the pattern of association of certain ores with certain intrusives or with positive aeromagnetic anomalies suggests that the aeromagnetic data can be used as a prospecting tool in some areas not yet thoroughly explored.

Kleinkopf was responsible for interpretation of the aeromagnetic data, which have been previously released for public use through an open-file report and publications of the U.S. Geological Survey (U.S. Geol. Survey, 1969a, 1969b-k; Meuschke and others, 1962). Harrison compiled the geologic data from many sources (see index map), and he made only minor changes from the published maps where it was essential to join various segments. Areas inadequately mapped for compilation at 1:250,000 were left blank on the map except for a few important faults or contacts, which are shown in dashed or dotted lines. Zartman was responsible for interpretation of the isotopic data. Inferences as to the significance of the three types of data are preliminary but are mutual among the three authors.

GENERAL GEOLOGY

Rocks of the mapped area belong dominantly to the Precambrian Belt Supergroup, a stratigraphic sequence at least 42,000 feet thick (the base is not exposed) of argillite, siltite, quartzite, and, in minor amounts, carbonate rocks. The oldest unit is the Prichard Formation, which consists characteristically of laminated black and gray pyritic or pyrrhotitic rusty-weathering argillite, gray argillite and siltite, and, in the lower part, gray impure quartzite. Next younger is the Ravalli Group, which consists of three units. The lower unit (the Burke Formation) is gray to purple-streaked magnetite-speckled siltite interbedded with lesser amounts of green to purple argillite. The middle unit of the Ravalli is the Revett Formation, which contains characteristic beds of white, tan, or purple-streaked blocky crossbedded quartzite. This unit thins from about 2,000 feet in the west to a few hundred feet in the northeast. The upper unit of the Ravalli is the St. Regis Formation in the southern and western parts of the area and the Grinnell Argillite in the northeastern part. The St. Regis is an interbedded carbonate-bearing sequence of purple argillite and siltite; it thins from southwest to northeast and has not been identified east of Libby, Mont. The Grinnell is dominantly purple argillite, but contains a few green argillite and light-colored siltite or quartzite beds, some of which are carbonate bearing. Overlying the Ravalli Group are the two carbonate-bearing formations, the Wallace Formation and its stratigraphic equivalent, the Helena Formation. The Wallace, which is a thick sequence of carbonate-bearing laminated black and white argillite, green argillaceous siltite, and sparse beds of limestone or dolomite, is exposed in most of the area. In the northeastern part of the area, this stratigraphic interval is represented by the Helena Formation, which contains some of the black and white argillite and green siltite beds similar to the Wallace Formation but which has thicker and more abundant layers of limestone and dolomite. Overlying the Wallace Formation are rocks of the Missoula Group. These rocks are dominantly red and green argillites, siltites, and quartzites that contain a few dolomite beds or dolomitic layers. The Missoula Group thins from about 16,000 feet in the southeast to about 4,000 feet in the Pend Oreille Lake area; part of the thinning is due to erosion that occurred before deposition of Cambrian sediments. All formations in the Missoula Group are thicker in the southeast, and subtle unconformities within the group appear to have cut out or thinned some formations; an example is the conspicuous red feldspathic quartzite (Lupine Quartzite) that is about 3,000 feet thick near Superior, Mont., but thins to about 700 feet near Pend Oreille Lake where it forms the upper member of the Striped Peak Formation.

Metamorphism of the Belt rocks increases from east to west and with depth in the stratigraphic section. Rocks of the Burke Formation and those immediately below the Burke are in the biotite zone of the greenschist facies. In the northwestern and southwestern parts of the area, Belt rocks are now schists and gneisses.

Belt rocks are overlain unconformably in a few places by Paleozoic sedimentary rocks. The basal unit (the Flathead Quartzite or its equivalents) is a quartzite.

Structurally, the area is basically a Precambrian anticlinorium of north-northwest-trending folds and faults. This simple structure was modified in Precambrian time by right-lateral offset on the ancestral Osburn and Hope fault zones that trend west-northwest across the area. It was further complicated by late Cenozoic block faulting that created basin-and-range structure, which now dominates most of the area north of the Osburn fault zone. The Libby Trough, which extends north-northwest across the central part of the area, contains dropped blocks of Paleozoic rocks. Preservation of the Paleozoic rocks is a conspicuous result of this block faulting, and the structural trough is probably more continuous than shown on the compilation. South of the Osburn fault zone, additional folds and faults, not yet completely understood but apparently of both Precambrian and younger ages, surround the Idaho batholith; the northern edge of the batholith is a few miles south of the mapped area. Late Cretaceous folding and thrusting at the eastern edge of the Kootenai arc mobile belt (west of the Purcell Trench) complicate the structural pattern in the northwest corner of the mapped area. Renewed movement on the Hope and Osburn fault systems in Tertiary time is also reasonably well documented.

Various types of igneous rocks have intruded or have been extruded onto the Belt rocks. Precambrian sills of quartz diorite or gabbro are particularly abundant in the northwestern part of the area. Many sills have been metamorphosed and altered, but a few retain a pronounced igneous texture and a moderate magnetite content. Cretaceous intrusive rocks show a wide range in composition and form. Most are plutons of granodiorite or quartz monzonite that have a contact metamorphic aureole a few thousand feet wide. One syenite pluton that has the most pronounced magnetic expression in the area is exposed on Vermiculite Mountain in the north-central part of the area. Tertiary intrusives are largely dikes and sills; some of them are porphyritic.

Relatively small exposures of Tertiary volcanic rocks include the isolated latitic and andesitic rocks in the east-central part of the area and the eastern edge of the vast Columbia River Basalt flows in the southwestern part of the area.

AEROMAGNETIC DATA

The aeromagnetic data were obtained from two surveys, one flown by Lockwood, Kessler, and Bartlett in 1968 and the other by the U.S. Geological Survey in 1959. The areas covered by these surveys are shown on the index map. Lockwood, Kessler, and Bartlett obtained data with a Mark III fluxgate magnetometer flown along east-west flight lines about 1 mile apart and at a barometric elevation of 7,000 feet. The U.S. Geological Survey recorded data with a fluxgate AN/ASQ-3A instrument flown along traverses ½-2 miles apart. The northern part was flown north-south at an average barometric elevation of 5,000 feet above sea level and the southern part was flown east-west at an average barometric elevation of 6,000 feet above sea level. Flight elevations were increased locally to clear high mountain peaks. The average geomagnetic field, which decreases about 6 gammas per mile in a southwestward direction, has not been removed.

RELATIONSHIPS OF MAGNETIC ANOMALIES TO GEOLOGY

The most intense magnetic anomalies on the map are related to three types of geologic sources that contain relatively high percentages of magnetite; these are igneous intrusives, major fault zones, and sedimentary rocks—specifically, the Ravalli Group. A few examples of each anomaly type will be discussed briefly to illustrate their geological significance.

Data secured from detailed investigations of magnetic anomalies that are associated with intrusives north and southeast of Pend Oreille Lake (Harrison and others, 1961; King and others, 1970; Harrison and others, in press) are useful in studying magnetic anomalies in the rest of the area. Southeast of Pend Oreille Lake, positive magnetic anomalies were found to correlate with Cretaceous granodiorite cupolas and stocks that are exposed and with those that are buried but are known to exist because of exposed contact metamorphic rocks (King and others, 1970). Harrison and others (in press) noted that to the north across the Hope fault magnetic anomalies are caused principally by dacite porphyry dikes and granodiorite intrusives. Most of the magnetic features associated with exposed intrusives are circular positive anomalies 200-400 γ in amplitude. The magnetic data also provide information about the subsurface extent of exposed intrusives and locations of concealed intrusives.

An elongate positive anomaly 200-300 γ in amplitude correlates with the outcrops of the Gem stock cluster just north-northeast of Wallace (T. 48 N., R. 4 E.). Hobbs, Griggs, Wallace, and Campbell (1965), in their geologic study of the Coeur d'Alene district, noted that an earlier aeromagnetic survey (their pl. 8) flown by the U.S. Geological Survey effectively outlined the monzonite stocks. Analysis of samples in the laboratory showed monzonite to be moderately magnetic; magnetic susceptibility values of four samples averaged 0.003 emu/cm^3.

Twelve miles northeast of the Gem stocks (T. 22 N., R. 31 W.), an unmapped area, a positive anomaly about 400 γ in amplitude suggests the presence of an intrusive. A cursory field examination revealed the presence of monzonitic rocks on the surface; the extent of the exposure, however, was not determined.

The circular positive anomaly just northeast of Thompson Falls (T. 21 N., R. 29 W.) may be due to a buried intrusive. The geology is not well known in this area. The outcropping Ravalli Group rocks mapped near the ridgetop may contribute to the anomaly; but the high amplitude (200 γ), the circular plan of the anomaly, and the reported occurrence of tungsten are indicative of an igneous intrusive source for the anomaly.

A positive anomaly of 400 γ in amplitude is related to the igneous intrusive exposed 2 miles east of Trout Creek village (T. 24 N., R. 31 W.). The offset of the anomaly northward relative to the outcrop and the steep gradient on the north side of the anomaly suggest that the intrusive extends north at shallow depth beneath the outcrop of the Prichard Formation.

The Libby stock at Vermiculite Mountain (T. 31 N., R. 30 W.), just northeast of Libby, gives rise to an exceptionally large anomaly of about 3,000 γ. Larsen and Pardee (1929) described the alkaline rocks of the stock as syenite that locally contains 3-12 percent magnetite; this amount of magnetite would account for the high amplitude of this anomaly. Another outcrop of intrusives 12 miles southwest of Libby (T. 29 N., Rs. 32 and 33 W.) appears to be composite as indicated by the three isolated positive anomalies related to its eastern part and the low-gradient zone over its southwestern part.

The exposures of Columbia River Basalt near St. Joe in the southwestern part of the area (Tps. 45 and 46 N., Rs. 1 and 2 E.) give negative anomalies that suggest reversed polarity. Two adjacent Cretaceous intrusives show positive anomalies. To the east along the southern boundary of the Osburn fault zone several small positive anomalies over the Bitterroot Range (T. 45 N., Rs. 8 and 9 E.) are attributed to minor intrusives controlled by west- and northwest-trending structural features. At Gold and Ward Peaks (T. 18 N., R. 30 W.), located about 12 miles west of St. Regis, positive anomalies may indicate buried intrusives that are related to the outcropping diorite dikes mapped by Wallace and Hosterman (1956). Wallace and Hosterman have also described the Wishards northwest-trending sills (T. 46 N., R. 7 E.) of diorite composition 6 miles to the west; the diorite gives a narrow positive anomaly along the exposures of the sills.

Many positive magnetic anomalies shown on the map are associated with outcropping sedimentary rocks of the Ravalli Group. In contrast to the high-amplitude circular anomalies associated with many of the igneous intrusives, these "sedimentary" anomalies typically are 50-100 γ in amplitude and many are elongated along structural trends where outcrops of the Ravalli Group are topographically high. Reconnaissance field studies in the vicinity of Pleasant Valley (T. 28 N., R. 27 W.), Wolf Creek (T. 29 N., R. 28 W.), and McGregor Lake (T. 25 N., R. 26 W.) showed that positive anomalies are associated with the Burke Formation at the base of the Ravalli Group. Abundant euhedral magnetite grains were observed in hand specimens of the Burke Formation. Magnetic susceptibility values for three samples collected from outcrops of the Burke Formation along Wolf Creek ranged from 0.0010 to 0.0028 emu/cm^3; this range accounts for the low-amplitude positive anomalies. At other places, the Revett Formation, which overlies the Burke, also contains magnetite that may contribute to the "sedimentary" anomaly.

It is not always possible to distinguish "sedimentary" anomalies from anomalies caused by igneous intrusives. Some of the positive magnetic anomalies over sedimentary Burke terrane may indeed be caused by concealed igneous intrusives. A possible concealed igneous intrusive is indicated by the closed high of about 100 γ over Cable Mountain (T. 28 N., R. 31 W.). Small quartz diorite and gabbro sills exposed in this vicinity do not give detectable anomalies.

Major fault zones show perceptible magnetic expression. The Osburn fault system trends west-northwestward across the area in a zone about 15 miles wide that generally parallels parts of the valleys of the Clark Fork and St. Regis Rivers in Montana, and the South Fork of the Coeur d'Alene River in Idaho. Zones of high magnetic gradient and elongated positive and negative anomalies correlate with many of the structural features of the Osburn fault zone. Some of these positive anomalies correlate with ridgetops and topographic highs underlain by sedimentary rocks containing abundant magnetite (probably the Burke Formation). The northern boundary of the fault zone is defined by terminations of southwest to southeast magnetic trends that correlate with structural features related to Cenozoic block faulting in the area between the Libby Trough and the Purcell Trench. It is common for negative anomalies here to correlate with faults and graben valleys. Examples are the negative anomalies along the valley (T. 29 N., R. 33 W.) in which Bull Lake is located.

The Hope fault is delineated by contours in the magnetic data parallel to the fault. King, Harrison, and Griggs (1970) described the magnetic pattern along the fault in the Clark Fork area as smooth and flat on the south side and as variable in pattern on the juxtaposed northeast side. This general relationship is observed throughout the length of the Hope fault southeast to its intersection with the Osburn fault zone.

LEAD ISOTOPES AND ORE DEPOSITS

By Robert E. Zartman

The mineral deposit of many of the area's mining districts are found in fracture veins that are related to faults. The ability to distinguish between different episodes of ore deposition would be useful in unraveling the regional structural history. A geologically young mineralization, such as Mesozoic or Cenozoic, within a certain fault might not exclude the possibility of earlier movement on that fault, but a Precambrian mineralization certainly would prove the antiquity of it. Some ore deposits lie within or near intrusive and volcanic rocks—Precambrian mafic rock, Cretaceous granodiorite and quartz monzonite, and Tertiary volcanic rock contain lead mineralization—but many other deposits are located far from any exposed igneous rocks.

The isotopic composition of lead in nature changes with time owing to additions to the preexisting lead of new radiogenic lead that results from the radioactive decay of uranium and thorium present in the rocks. This phenomenon causes different deposits of lead to vary in isotopic characteristics and has been the basis of attempts to date such mineralization. (See, for example, Russell and Farquhar, 1960.) Although the evolution of lead is by no means always regular and the assignment of specific ages solely from isotope ratios is often impossible, nevertheless, two important episodes of ore deposition that are widely separated in time, as apparently occurs in the area under discussion, may produce distinct, recognizable lead isotopic families. Cannon, Pierce, Antweiler, and Buck (1962) were the first to call attention to different varieties of lead here—a so-called Coeur d'Alene type that has a 1.2- to 1.4-b.y. model age and another type which is more evolute and which ranges widely in isotopic composition. The first type is now usually regarded as having been deposited synchronously with or soon after Precambrian sedimentation of the Belt Supergroup, and the second type is believed to be considerably younger, probably originating during the Mesozoic and Cenozoic Eras.

Lead isotopic analyses published elsewhere (Zartman and Stacey, 1971; Cannon and others, 1962) have been used to distinguish between the Precambrian and the Mesozoic and Cenozoic ore deposits shown on the map. The reader is referred to the original reports for a description of individual mines and prospects. The lead isotopes can be interpreted with confidence only in terms of the gross time differences, and, although in a few instances geologic evidence allows for more specific age assignment, usually no age information is available from relationships determined in the field. Several conclusions based on these geologic aeromagnetic, and isotopic data which may be helpful in prospecting emerge from study of the map and they merit comment.

1. Major lead and silver deposits occur in the southern third of the mapped area along the prominent Osburn fault system. This mineralization, which includes that of the economically important Coeur d'Alene district, is interpreted as being Precambrian and, therefore, it is genetically unrelated to adjacent Cretaceous intrusions, such as the Gem stocks (although minor young deposits are recognized within some of the intrusions).
2. A second belt of Precambrian mineralization extends southward from the northern edge of the mapped area along the Idaho-Montana boundary. Along this belt are found the lead-zinc-copper deposits of the Troy district, the lead-silver deposits of the Blue Creek district, and several other isolated deposits. A close spatial relationship exists in several deposits between mineralization and Precambrian sills of altered quartz diorite. To the south, the belt apparently joins the Osburn fault system in the vicinity of Thompson Falls.
3. Mineralization in the northwestern part of the mapped area is interpreted as being Mesozoic and Cenozoic and as probably being related to faults and intrusive rocks of the Kootenai arc mobile belt. Mesozoic and Cenozoic deposits have also been identified in several localities in the central part of the mapped area. Many of these young ore bodies are associated with exposed Cretaceous or Tertiary igneous rocks or with discrete positive magnetic anomalies that are suggestive of shallow plutons.
4. Generally only small, isolated deposits both of Precambrian and of Mesozoic and Cenozoic age have been found in the weakly mineralized northeastern part of the mapped area. A notable exception is the Hog Heaven district (T. 25 N., R. 23 W.), where rich, but limited, occurrences of lead-silver ore were found associated with Tertiary volcanic andesites.

SUGGESTIONS FOR PROSPECTING

Several exposed intrusives and their associated mineralization show well-developed magnetic anomalies. Examples are at the Coeur d'Alene mining district (T. 48 N., Rs. 4 and 5 E.), where at least minor occurrences of lead are associated with the Gem stock monzonitic intrusion (Hobbs and others, 1965); at Vermiculite Mountain (T. 31 N., R. 30 W.), where vermiculite is associated with a syenite stock (Larsen and Pardee, 1929); and in an area northeast of Thompson Falls (T. 21 N., R. 29 W.), where tungsten occurrences have been reported in the vicinity of a probable buried intrusive that is suggested by the magnetic data. The lack of diagnostic magnetic anomalies associated with the prophyritic latite intrusive rocks of the Hog Heaven mining district (T. 25 N., R. 23 W.), where silver and lead have been mined, is probably due to the intense alteration described by Shenon and Taylor (1936).

Several localities have distinct high-amplitude positive anomalies that are indicative of buried intrusive rocks, though none have been found at the surface. These areas seem worthy of careful prospecting for possible mineral deposits that might be associated with the intrusives. Small sharp positive anomalies over the Ravalli Group at places do not exactly match the ridgetops. These too may be reinforcements of a sedimentary type anomaly by a buried pluton, and hence may indicate areas worth further prospecting. Areas where positive anomalies may indicate the presence of unmapped or blind intrusives are:

Cable Mountain, Elephant Peak, and Flattop Mountain located about 20 miles south-southwest of Libby (T. 28 N., R. 31 W.; T. 27 N., R. 31 W.; T. 26 N., R. 31 W., respectively).

Two locations, 7 and 12 miles east and east-southeast of Clark Fork (T. 56 N., R. 34 W.; T. 27 N., R. 34 W.).

About 3 miles east of Murray (Tps. 49 and 50 N., R. 5 E.).

Four miles northeast of Burke (Tps. 48 and 49 N., R. 32 W.).

Three miles southeast of Mullan (T. 47 N., Rs. 5 and 6 E.).

The ridgetop east of Dixie Peak, 12 miles northeast of Burke (T. 22 N., R. 31 W.).

Twenty Peak, 5 miles northeast of Trout Creek village (T. 25 N., R. 31 W.).

Four miles east-northeast of Thompson Falls (Tps. 21 and 22 N., R. 29 W.).

Gold Peak and Wards Peak, 12 miles west of St. Regis (T. 18 N., R. 8 E.; T. 17 N., R. 8 E., respectively).

Twenty miles south-southwest of St. Regis (Tps. 42 and 43 N., R. 10 E.).

Coney Peak, 7 miles northwest of Hot Springs (T. 22 N., R. 25 W.).

Near Elk Mountain, 29 miles east-northeast of Libby (T. 31 N., R. 26 W.).

Ridge east of Eddy Creek, 9 miles west of Plains (T. 20 N., R. 27 W.).

REFERENCES CITED

Campbell, A. B., 1960, Geology and mineral deposits of the St. Regis-Superior area, Mineral County, Montana: U.S. Geol. Survey Bull. 1082-I, p. 545-612 [1961].

Cannon, R. S., Jr., Pierce, A. P., Antweiler, J. C., and Buck, K. L., 1962, Lead-isotope studies in the northern Rockies, U.S.A. *in* Engel, A. E. J., James, H. L., and Leonard, B. F., eds., Petrologic studies (Buddington volume): Geol. Soc. America, p. 115-131.

Gibson, Russell, 1948, Geology and ore deposits of the Libby quadrangle, Montana, *with sections on* Pleistocene glaciation, by W. C. Alden, and Physiography, by J. T. Pardee: U.S. Geol. Survey Bull. 956, 131 p.

Gibson, Russell, Jenks, W. F., and Campbell, Ian, 1941, Stratigraphy of the Belt Series in Libby and Trout Creek quadrangles, northwestern Montana and northern Idaho: Geol. Soc. America Bull., v. 52, no. 3, p. 363-379.

Griggs, A. B., 1969, Geologic map of the east half of the Spokane 1° by 2° sheet: U.S. Geol. Survey open-file map.

Harrison, J. E., 1969, Geologic map of part of the Mount Pend Oreille quadrangle, Idaho-Montana: U.S. Geol. Survey open-file map.

_____ 1971, Geologic map of the Elmira quadrangle, Idaho: U.S. Geol. Survey Geol. Quad. Map GQ-953 (in press).

Harrison, J. E., and Jobin, D. A., 1963, Geology of the Clark Fork quadrangle, Idaho-Montana: U.S. Geol. Survey Bull. 1141-K, 38 p.

_____ 1965, Geologic map of the Packsaddle Mountain quadrangle, Idaho: U.S. Geol. Survey Geol. Quad. Map GQ-375.

Harrison, J. E., Jobin, D. A., and King, Elizabeth, 1961, Structure of the Clark Fork area, Idaho-Montana *in* Short papers in the geologic and hydrologic sciences: U.S. Geol. Survey Prof. Paper 424-B, p. B159-B163.

Harrison, J. E., Kleinkopf, M. D., and Obradovich, J. D., 1971, Tectonic events at the intersection between the Hope fault and the Purcell Trench: U.S. Geol. Survey Prof. Paper (in press).

Hietanen, Anna, 1967, Scapolite in the Belt Series in the St. Joe-Clearwater region, Idaho: Geol. Soc. America Spec. Paper 86, 56 p.

_____ 1968, Belt Series in the region around Snow Peak and Mallard Peak, Idaho: U.S. Geol. Survey Prof. Paper 344-E, 34 p.

Hobbs, S. W., Griggs, A. B., Wallace, R. E., and Campbell, A. B., 1965, Geology of the Couer d'Alene district, Shoshone County, Idaho: U.S. Geol. Survey Prof. Paper 478, 139 p.

Hosterman, J. W., 1956, Geology of the Murray area, Shoshone County, Idaho: U.S. Geol. Survey Bull. 1027-P, p. 725-748.

Johns, W. M., 1960, Southeastern Lincoln County, Pt. 2 *of* Progress report on geologic investigations in the Kootenai-Flathead area, northwest Montana: Montana Bur. Mines and Geology Bull. 17, 52 p.

_____ 1962, Southwestern Flathead County, Rept. 4 *of* Progress report on geologic investigations in the Kootenai-Flathead area, northwest Montana: Montana Bur. Mines and Geology Bull. 29, 38 p.

_____ 1964, Southeastern Flathead County and northern Lake County, [Pt.] 6 *of* Progress report on geologic investigations in the Kootenai-Flathead area, northwest Montana: Montana Bur. Mines and Geology Bull. 42, 66 p.

Johns, W. M., Smith, A. G., Barnes, W. C., Gilmour, E. H., and Page, W. D., 1963, Western Flathead County and part of Lincoln County, Rept. 5 *of* Progress report on geologic investigations in the Kootenai-Flathead area, northwest Montana: Montana Bur. Mines and Geology Bull. 36, 68 p.

King, E. R., Harrison, J. E., and Griggs, A. B., 1970, Geologic implications of aeromagnetic data in the Pend Oreille area, Idaho-Montana: U.S. Geol. Survey Prof. Paper 646-D, 17 p.

Larsen, E. S., and Pardee, J. T., 1929, The stock of alkaline rocks near Libby, Montana: Jour. Geology, v. 37, no. 2, p. 97-112.

Meuschke, J. L., McCaslin, W. E., and others, 1962, Aeromagnetic map of part of the Pend Oreille area, Idaho: U.S. Geol. Survey open-file report.

Russell, R. D., and Farquhar, R. M., 1960, Lead isotopes in geology: New York, Interscience Publishers, 243 p.

Shenon, P. J., and Taylor, A. V., Jr., 1936, Geology and ore occurrence of the Hog Heaven mining district, Flathead County, Montana: Montana Bur. Mines and Geology Mem. 17, 26 p.

U.S. Geological Survey, 1969a, Aeromagnetic survey, northeastern Idaho and western Montana: U.S. Geol. Survey open-file report.

_____ 1969b, Aeromagnetic map of the Libby and Mt. Pend Oreille quadrangles, Lincoln and Sanders Counties, Montana, and Bonner County, Idaho: U.S. Geol. Survey Geophys. Inv. Map GP-682.

_____ 1969c, Aeromagnetic map of the Thompson Lakes quadrangle, Lincoln, Sanders, and Flathead Counties, Montana: U.S. Geol. Survey Geophys. Inv. Map GP-683.

_____ 1969d, Aeromagnetic map of the McGregor Lake-Tally Lake area, Flathead and Lincoln Counties, Montana: U.S. Geol. Survey Geophys. Inv. Map GP-684.

_____ 1969e, Aeromagnetic map of the Trout Creek quadrangle, Sanders and Lincoln Counties, Montana, and Shoshone County, Idaho: U.S. Geol. Survey Geophys. Inv. Map GP-685.

_____ 1969f, Aeromagnetic map of the Thompson Falls quadrangle, Lincoln and Sanders Counties, Montana: U.S. Geol. Survey Geophys. Inv. Map GP-686.

_____ 1969g, Aeromagnetic map of the Hubbart Reservoir-Hot Springs area, Sanders, Flathead, and Lake Counties, Montana: U.S. Geol. Survey Geophys. Inv. Map GP-687.

——— 1969h, Aeromagnetic map of the Kingston, Kellogg, and part of the Fernwood quadrangles, Shoshone, Benewah, and Kootenai Counties, Idaho: U.S. Geol. Survey Geophys. Inv. Map GP-688.

——— 1969i, Aeromagnetic map of part of the Avery quadrangle, Shoshone County, Idaho, and Mineral and Sanders Counties, Montana: U.S. Geol. Survey Geophys. Inv. Map GP-689.

——— 1969j, Aeromagnetic map of the Haugan and St. Regis quadrangles and parts of the Simmons Peak and Illinois Peak quadrangles, Shoshone County, Idaho, and Mineral and Sanders Counties, Montana: U.S. Geol. Survey Geophys. Inv. Map GP-690.

——— 1969k, Aeromagnetic map of the Plains, Perma, Superior, and Tarkio quadrangles, Sanders, Mineral, and Missoula Counties, Montana: U.S. Geol. Survey Geophys. Inv. Map GP-691.

Wagner, W. R., 1949, The geology of part of the south slope of the St. Joe Mountains, Shoshone County, Idaho: Idaho Bur. Mines and Geology Pamph. 82, 48 p.

Wallace, R. E., and Hosterman, J. W., 1956, Reconnaissance geology of western Mineral County, Montana: U.S. Geol. Survey Bull. 1027-M, p. 575-612.

Zartman, R. E., and Stacey, J. S., 1971, Lead isotopes and mineralization ages in Belt Supergroup rocks, northwestern Montana and northern Idaho: Econ. Geol., v. 66.