DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
MONTANA BUREAU OF MINES AND GEOLOGY

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I-1509-A (SHEET 2 OF 2)

Base from U.S. Geological Survey, 1956, revised 1981
100,000-foot grid based on Montana coordinate system central and north zones, and Idaho coordinate system, west zone

SCALE 1:250 000

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100-FOOT INTERVALS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1986—G84152

Geology by J.E. Harrison, A.B. Griggs, and J.D. Wells, 1970–80; assisted by H.R. Covington, 1972; Joseph Boggs, 1973; and J.P. Harrison, 1970–80

Table 1.—*Approximate age of principal tectonic, magmatic, and geologic events in the Wallace 1° x 2° quadrangle*

Approximate age in millions of years	Tectonic or magmatic event	Geologic event
0–2	Minor renewed movement along a few high-angle faults.	Alluvium deposited in present stream valleys; placer gold deposits formed in some. Continental glacial debris deposited over much of the terrain drained by Flathead River; alpine glacial deposits scattered over entire area. Tertiary sediments tilted at places.
35(?)–120	Easterly directed listric thrusting north of Lewis and Clark line, accompanied by right-lateral movement in the line and along other major strike-slip faults; intrusion of mafic dikes and mafic to felsic plutons; northerly to northeasterly glide and listric thrusting within, south of, and overriding Lewis and Clark line; high-angle horst-and-graben faulting; minor volcanism. Broad open folding in plates above thrust soles and in front of listric thrusts; overturning and some tight folding near thrust soles and in a few plates. Small volcanic center formed in northeastern part of quadrangle.	Broad gentle folding in upper plates, tight upright to overturned folding near many listric thrust soles; listric thrusts tend to be cut by horst-and-graben faults, whereas flat thrusts tend not to be cut but do transport some high-angle faults; plutons intrude thrusts. Tertiary dikes in southwest were intruded along axial-plane cleavage of tight folds. Tertiary sediments and volcanic deposits filled older valleys and stream courses. Sulfide mineralization accompanied some intrusions and volcanic activity. Contact metamorphism near smaller plutons; widespread in southwest near Idaho batholith. Widespread heating at about 50 million years.
120–550	No record of events.	Erosion of unknown amount of Proterozoic, Paleozoic, and Mesozoic rocks.
550	Subsidence and minor faulting.	Deposition of lower Middle Cambrian sediments (perhaps continuing on to include other Paleozoic and Mesozoic sediments).
800(?)	Left(?)-lateral movement and high-angle faulting, mostly in Lewis and Clark line. Uplift and gentle warping or folding.	Tight upright to overturned folding in western part of Lewis and Clark line. Emplacement of Coeur d'Alene veins and other base- and precious-metal veins. Erosion of unknown amount of Belt rocks.
850–1,450	Periodic relative downwarping in Belt basin accompanied by minor faulting in Lewis and Clark line. Three episodes of mafic intrusion.	Deposition of Belt sediment on cratonic pre-Belt basement; regional metamorphism (depth of burial plus additional regional geothermal gradient). Basic sills intruded at about 1,430, 1,100(?), and 800 million years.
1,700–2,200 +	Undetermined amounts of tectonism and magmatism.	Formation of deformed amphibolite-facies metamorphic rocks. Intrusion of anorthosite.

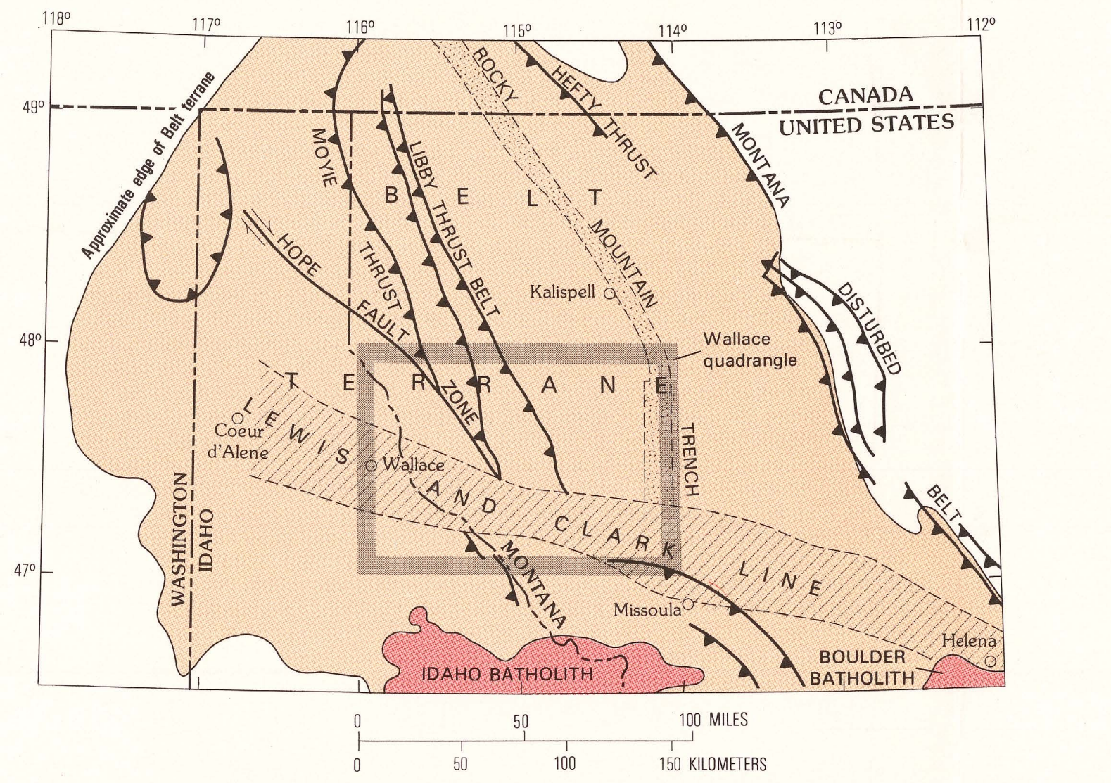

Figure 3.—INDEX MAP SHOWING REGIONAL STRUCTURES NEAR THE WALLACE QUADRANGLE

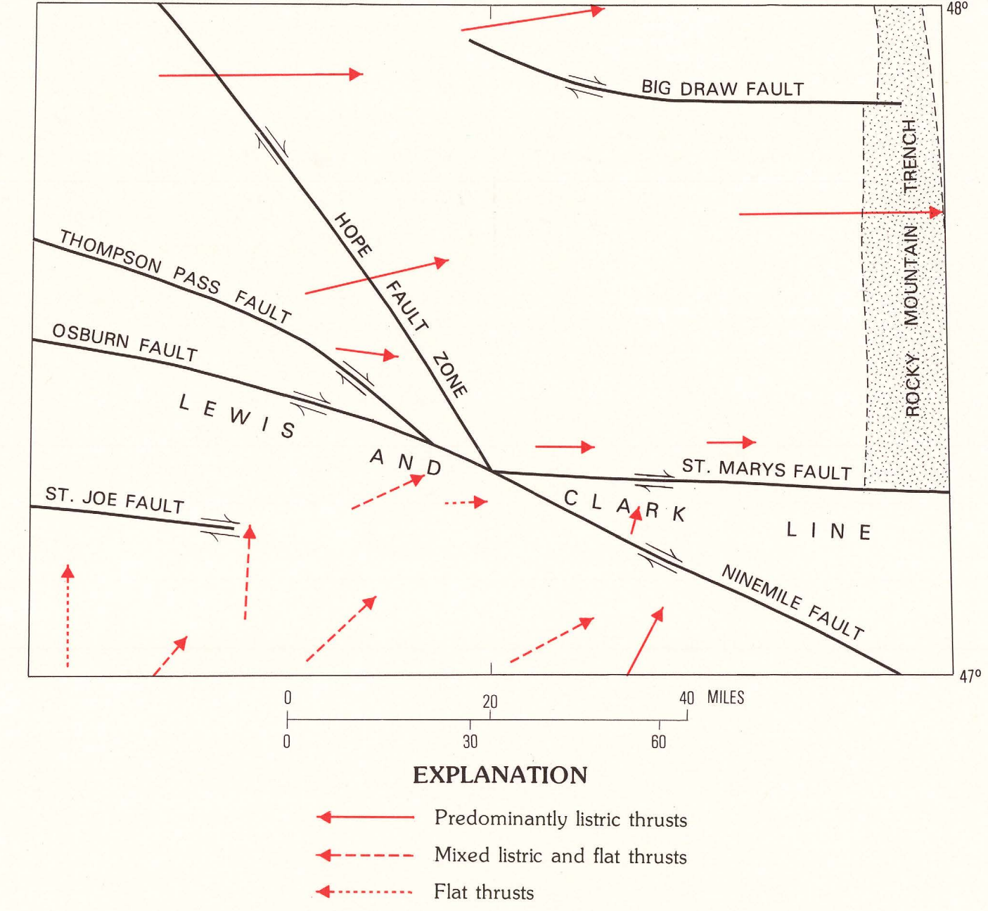

Figure 4.—SKETCH MAP SHOWING DIRECTIONS OF TRANSPORT AND PROBABLE TYPES OF THRUSTS. Length of each arrow crudely indicates the relative amount of tectonic transport.

EXPLANATION

FAULTS—Dotted where inferred
- Fault—Bar and ball on downthrown side; arrows show direction of apparent strike slip
- Thrust—Sawteeth on upper plate

FOLDS—Showing trace of axial plane
- Anticline—Showing direction of plunge
- Overturned anticline—Showing direction of dip of limbs
- Syncline—Showing direction of plunge
- Overturned syncline—Showing direction of dip of limbs
- Terrace or monoclinal fold—Showing direction of plunge

BEDDING
- 26 Inclined—Showing strike and dip
- 40 Overturned—Showing strike and dip
- Vertical
- ⊕ Horizontal
- 43 34 Inclined—Showing bearing and plunge of secondary lineation

FOLIATION
- 32 Inclined—Showing strike and dip where known
- 64 16 Inclined—Showing bearing and plunge of lineation
- 25 Inclined—Showing horizontal lineation

MAJOR STRUCTURAL FEATURES

The Wallace quadrangle contains parts of several major structural features that extend many tens of kilometers beyond the quadrangle (fig. 3). Among these are the Lewis and Clark line, the Rocky Mountain trench, the Hope fault zone, major thrust systems, and extensive horst-and-graben faults. Folds in the quadrangle formed largely in response to the same stresses that caused the faulting. The regional setting and tectonic interpretation, based in part on data from the Wallace quadrangle, have been presented elsewhere (Harrison and others, 1974, 1980). The following sections identify and discuss briefly the parts of the major structural features and fold patterns identifiable in the Wallace quadrangle. The principal tectonic and magmatic events for the area are summarized in table 1.

LEWIS AND CLARK LINE

The pronounced zone of nearly vertical normal, reverse, and strike-slip faults extending from the west-central to the southeastern part of the map is part of the Lewis and Clark line, which was first recognized and named by Billingsley and Locke (1939). This fault zone reflects a zone of crustal weakness along which movement has occurred intermittently from the Proterozoic into the Quaternary. Although the zone seems sharply defined on small-scale maps, such as those of a State or the United States, boundaries on larger scale maps are not so precise. The northern boundary in the Wallace quadrangle is more or less defined from west to east by the strike-slip faults that include the Thompson Pass fault, a segment of the Osburn-Ninemile faults, and the St. Marys fault. The southern boundary is not as precise; it starts on the west with the St. Joe fault, but in a few kilometers becomes involved with thrust plates that override the line and with dip-slip faults that cut the thrusts. Which fault forms the southern boundry is open to question. The western end of the line contains vein systems of the Coeur d'Alene mining district. Lead isotopes from that district are Precambrian in age, as is galena in veins that fill fractures elsewhere within the line (Zartman and Stacey, 1971; Kleinkopf and others, 1972; Marvin and others, 1984), and these attest to the antiquity of the zone. Where strike-slip faults of the zone occur in braided strands, form cymoid loops, or abruptly change strike, gouge and breccia zones as much as a kilometer wide have been formed; along structurally uncomplicated straight parts of the same faults, few or no gouge or broken zones occur.

Faults of the Lewis and Clark line have a complex history, and many of them likely have had movement along them several times (Harrison and others, 1974). The youngest movement in the Wallace quadrangle is recorded along the Ninemile fault, where Tertiary sedimentary and volcanic rocks that filled Ninemile valley have been tilted northward toward the Ninemile fault.

ROCKY MOUNTAIN TRENCH

The long and wide north-trending valley that includes most of Flathead Lake at the east edge of the quadrangle is the southern end of the Rocky Mountain trench, a physiographic feature that extends northward more or less continuously through Montana and across Canada into Alaska. Structurally, the small segment in the Wallace quadrangle is a zone of closely spaced horst-and-graben faults. This zone and the trench end abruptly at the St. Marys fault. The west edge of the trench, as defined by the north-south horst-and-graben faults, is offset by about 8 km of right-lateral movement along the Big Draw fault. This amount of offset corresponds almost exactly with the amount of right-lateral displacement of fold axes across the Big Draw fault. Projections of faults through Flathead Lake are based on seismic reflection profiles across the lake (Wold, 1982), as well as on projections of surface geologic data near the lake.

HOPE FAULT ZONE

This zone of apparent right-lateral and down-to-the-southwest displacement is followed by the Clark Fork valley from Thompson Falls, Mont., northwestward for 50 km beyond the edge of the Wallace quadrangle into the panhandle of Idaho (see fig. 3). Sparse exposures show steep south dips on faults of the zone. The faults here are similar to the strike-slip faults of the Lewis and Clark line: minimal gouge or breccia along straight parts, as well as wide zones of gouge along cymoid loops or at relatively abrupt changes in strike. A sharp bend in the Clark Fork river about 16 km northwest of Thompson Falls cuts into rocks known as the "Blue Slide," a feature composed of a wide gouge zone along a broad bend in the Hope fault zone.

The Hope fault zone joins the north-bounding faults of the Lewis and Clark line and shares the apparent right-lateral offset of the line. Geologic relations of Proterozoic sills near the northwestern end of the Hope fault zone in Idaho suggest a Proterozoic ancestry for the Hope, and renewed movement in the Eocene can be documented (Harrison and others, 1972, 1974).

THRUST FAULTS

All the Proterozoic bedrock in the Wallace quadrangle has been carried into this region on thrust faults. For convenience in discussion, the thrusts can be grouped into those north of the Lewis and Clark line and those within and south of the line.

Most of the thrust faults north of the Lewis and Clark line dip west; those in the Libby thrust belt (fig. 3) tend to be steep, whereas others outside that belt may be steep or may dip at less than 45°. Local fold axes parallel the north trend of most thrusts, and the few slickensides found on thrust soles trend about east-west. These faults represent tectonic transport from west to east, are part of an extensive system of thrust faults that cuts Belt terrane, and have been interpreted to result from plate interactions that began about 200 m.y. ago along the western continental margin (Harrison and others, 1980). The long arrow shown across the Rocky Mountain trench in figure 4 has no thrust zone at its point in the Wallace quadrangle. The arrow is shown to recognize the fact that the leading edge of the Montana thrust belt is still about 100 km to the east and that rocks in the area of the arrow are also allochthonous, even though no indication of that fact shows on the geologic map of the Wallace quadrangle.

Two notable exceptions to the general pattern of thrusting north of the Lewis and Clark line include short thrusts hinged to the north and a klippe that dips east. Hinged thrusts, those that in plan view start in a fold and show increasing translation away from the fold, include the north-trending thrust near Perma, Mont., and the north-northwest-trending thrust east of Eddy Mountain near the center of the quadrangle (maps ***A*** and ***B***). Both thrust faults start from an anticline at the north end and stop at the south against a right-lateral fault of the Lewis and Clark line. The geometry of these thrusts requires a greater movement where they abut the line than at the hinge point and also requires a slight counterclockwise rotation on the thrusts. They may have resulted from minor adjustments to the movement along the Hope-St. Marys faults 50 m.y. ago, rather than from the 100-m.y.-old major eastward movement (Harrison and others, 1980) postulated for thrusts north of the Lewis and Clark line. The small klippe near the mouth of the Little Thompson River in the north-central part of the quadrangle is an apparent east-dipping erosional remnant of the thrust that is 2 km to the southwest. The gentle east dip of the klippe may be due to folding of the thrust or, more likely, to tilting on the down-dropped side of the high-angle normal fault that cuts off the east side of the klippe.

Thrust faults within and south of the Lewis and Clark line are moderately steep to subhorizontal, and the thrust plates vary in structural style from area to area. Many thrust plates are gently folded or dip homoclinally, but show upright to overturned tight folds of tens to hundreds of feet in amplitude near their leading traces; some contain asymmetric chevron folds indicating up-to-the-north movement throughout the upper plate; and some show little or no folding even at the sole of the thrust. The soles of a few of the thrusts are altered or feldspathized. The series of thrust plates in the south-central area have been mapped as thrust segments bounded by tear faults. The straight and steep tear faults are required by the map pattern (map ***A***), which also suggests that some vertical movement has occurred on some tear faults, presumably after thrusting. The direction of tearing combined with fold axes that are subparallel to the trace of the thrusts at their leading edges suggest north to northeast directions of translation on the thrusts. Metamorphic isograds related to the Idaho batholith (Hietanen, 1963, 1968; Lang and Rice, 1982, and oral commun., 1982) extend without interruption across both the thrust plates and high-angle faults of the area. Thus, the structures are older than the emplacement of the northern lobe of the batholith at about 70-50 m.y. ago (Armstrong and others, 1977).

Thrust faults within the Lewis and Clark line in the southern part of the quadrangle have overridden the line, and the thrust plates have subsequently been moved up and down on high-angle faults of the line. Some of the resulting complexity is illustrated at the south (left) end of section ***B—B′*** accompanying map ***A***. Axes of folds on the thrust plates combined with very sparse measurements of slickensides on some poorly exposed thrust soles suggest a general northeasterly transport on the thrusts.

One small klippe at Marble Point about 10 km south of Saint Regis, Mont., contains internally contorted and sheared beds, structures not common to any other thrust plate. The klippe is interpreted as a relatively young glide block that slid into its present position from the higher ground to the southwest, before erosion removed all the Missoula Group rocks from that area.

Geologic interpretation of the major thrust faults in the southern part of the area is complicated by an almost total lack of adequate geologic data in an area of about 1,500 km^2 between the south edge of the Wallace quadrangle and the Idaho batholith. The easternmost thrust faults at the south edge of the area can be traced southeastward out of the quadrangle, where they swing to a southeasterly trend and apparently join an intense zone of easterly directed thrusting on the east side of the Idaho batholith (Wallace and others, 1981). It seems likely that most of the thrusting is related to the general west-to-east movement in the wide zone of overthrusting of the Montana and Wyoming thrust belts. To expect that a relatively small segment between the Lewis and Clark line and the present position of the Idaho batholith remained untouched and unmoved seems unrealistic. The trends and apparent directions of translation of the few thrusts mapped to date in the area appear somewhat anomalous in that they have a north-to-northeast rather than an east direction of transport. This apparent anomaly could be due to a local resolution of stresses during major overthrusting events along a preexisting major crustal flaw, the Lewis and Clark line, or it might be caused by later tilting or other deformation related to the intrusion and eventual uplift and unroofing of the Idaho batholith.

LOW-ANGLE NORMAL FAULTS

Low-angle normal faults are rare in the quadrangle and are confined to the Lewis and Clark line. At the west end of the line, a low-angle normal fault offsets the tops of small plutons (the Gem stocks, unit **Kg**) about 5 km westward. Other such faults occur between two strands of the Lewis and Clark line about 12 km north of Tarkio, Mont.

HIGH-ANGLE NORMAL AND REVERSE FAULTS

High-angle normal and reverse faults are abundant in the Wallace quadrangle, but only the larger or more persistent or better exposed ones are shown at this map scale. Individual faults show a few tens to a few thousands of feet of movement along them. Most faults are steep to vertical, as shown by their relatively straight traces across the topography as well as by observations at the few good exposures. Intersections between two steep faults or between a steep fault and a vaguely defined trace of a vertical axial plane of a fold commonly show no significant offset either on the ground or at the scale of the map. Most faults show normal drag folding along them, but some show reverse drag folds or pronounced drag folds accompanied by little or no apparent stratigraphic offset. Penetrative cleavage is common in rocks within a few tens of feet of the high-angle faults.

Much of the topography in the quadrangle began to form during Tertiary time when faulting and cleavage fractured the terrane and formed elongate depressions that were filled by Tertiary sediments. A long period of erosion, which continues even today, excavated these softer rocks and, aided at places by Pleistocene glaciation, differentially wore away the cleaved, broken, and gouge zones along most faults. Thus, even in areas of poor outcrop or heavy timber, traces of many faults are well defined by alined notches on adjacent ridge tops, stream courses, or steep and straight valley walls.

The high-angle faults are not readily classified or grouped into sets. In general, such faults in and near the Lewis and Clark line trend west-northwest subparallel to the line. Two other obvious trends are near north and about N. 30° W. These groups of faults intersect or abut at many places, but neither group consistently cuts the other. The prominent north-trending, closely spaced faults at the south end of Flathead Lake are characteristic of faults in the Rocky Mountain trench, but they turn northwest with the trench north of the quadrangle (fig. 3) and continue as a N. 30° W. set. In almost all areas of the quadrangle where thrusts and high-angle faults coexist, the thrusts are offset by the high-angle faults. One exception is near the south edge of the map west of Tarkio, Mont., where high-angle faults have been carried along on two thrust plates.

AGE AND INTERPRETATION OF HIGH-ANGLE FAULTS

Several ages of high-angle faulting are represented in the quadrangle, and many faults have probably had recurrent movement along them. Proterozoic disturbance within the Lewis and Clark line is demonstrated by large slump structures and fault breccia in the Prichard Formation near Plains, Mont. (Cressman, 1981), and by soft-sediment deformation in the St. Regis Formation in the Coeur d'Alene district (Chevillon, 1977). Galena of Precambrian age in many faults along the line (Zartman and Stacey, 1971; Kleinkopf and others, 1972; Marvin and others, 1984) also supports a Proterozoic ancestry for some fractures. Intrusive rocks of Late Cretaceous and early Tertiary age cut known thrusts (see section ***A–A′***, map ***A***, for example), which in turn are cut by many high-angle faults. These age relations, along with tilting of Tertiary sediments and intrusion of Tertiary dikes along faults (Marvin and others, 1984), attest to high-angle faulting of Phanerozoic age.

The high-angle normal and reverse faults of the north and N. 30° W. trends are interpreted as horst-and-graben structures. Cross faults extend between some of the horst-and-graben faults to complete a typical pattern of extension in highly fractured ground. Most of the horst-and-graben faults are possibly listric normal faults and faults antithetic to them that extend down to various thrust faults underlying the horst-and-graben terrane at depth; however, without borehole or seismic data to help interpret the subsurface geology, these faults are shown as simple high-angle faults in the cross sections on map ***A***, and the probable deep thrusts are omitted. Horst-and-graben faults cut at a low strike angle both the thrust faults and the folds associated with them. If all these features are part of one major event, then the compressional stress resulting in thrusting and folding was not quite parallel to the extensional stress that led to horst-and-graben faulting.

FOLDS

Tight upright to overturned folds characterize the western part of the Lewis and Clark line (section ***A–A′***, map ***A***). These have been interpreted (Hobbs and others, 1965) to be the result of stress within wedge-shaped blocks in the line when movement occurred along the line in Late Proterozoic time.

The amount of warping or folding that occurred outside the Lewis and Clark line in Late Proterozoic time (at least in pre-Middle Cambrian or Flathead Quartzite time) is uncertain, but some was required. The unmetamorphosed Flathead Quartzite or its equivalent rests on various Proterozoic stratigraphic units (Belt Supergroup) that show greenschist facies metamorphic grades, and this required a significant amount of uplift between Belt time and Flathead time. In addition, several thousand feet of Belt rocks had been eroded from subjacent fault blocks prior to deposition of the Flathead Quartzite. Hobbs and others (1965) argue convincingly that in the Coeur d'Alene area a major north-trending open fold was deformed by Late Proterozoic movement along the Lewis and Clark line.

Broad open folds and terrace folds are common in the quadrangle. These are interpreted as upper plate structures relatively high in the plate above the sole or as local compressional structures parallel to but in front of leading edges of listric thrusts. Some of the broad open folds, however, may be gently refolded Proterozoic folds rather than folds formed only in response to thrusting of Mesozoic-Cenozoic age.

Folds at or near soles of thrust faults are common, although a few bedding-plane thrust faults have little deflection at their soles. Folds found near soles of thrust faults commonly have traces of axial planes that are subparallel to the traces of the thrust faults with which they are associated; the plates above these thrust faults commonly contain vertical to overturned strata. The trace of the axial plane of such folds would superpose over the trace of the thrust fault at the scale of the Wallace quadrangle and cannot be shown.

Closely spaced chevron folding characterizes some of the thrust plates in the southwestern part of the quadrangle. Basic dikes of Tertiary age south of Black Jack Peak are deformed along their edges and have been intruded along axial-plane cleavage in the chevron folds (map ***A***). These data suggest that the folding and dike intrusion were contemporaneous.

The southwestern corner of the quadrangle contains a small area of highly deformed amphibolite facies rocks of pre-Belt age. We made no attempt to work out the complex geologic history of these rocks from such a small sample of a similar and extensive terrane known to exist south of the map area.

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B. Structure map

GEOLOGIC AND STRUCTURE MAPS OF THE WALLACE 1° x 2° QUADRANGLE, MONTANA AND IDAHO

By

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1986

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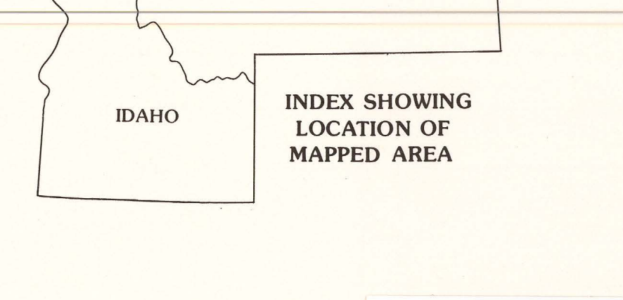

INDEX SHOWING LOCATION OF MAPPED AREA

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