Explanation:

- Well that penetrates bedrock
- MB-2 Deep well from Norbeck (1980)
- 500 Contour of bedrock, altitude above mean sea level (ft); irregular interval, dependent on data quality
- Approximate contour
- Inferred contour (from gravity geophysical data)
- Basin fill: Quaternary sediments and Tertiary sedimentary rocks
- Tm Tertiary metamorphic rocks on Bitterroot Range front
- TKi Tertiary and Cretaceous intrusive rocks
- Pzb Paleozoic sedimentary rocks
- Yb Proterozoic Belt Supergroup rocks
- Study area boundary
- Township boundary
- Section boundary
- Major road
- Principal river or stream
- Lake or reservoir
- River floodplain area
- City or town

Figure 1. Altitude of bedrock in Mineral and Missoula counties.

Figure 2. Index map showing the principal cities, drainages, and physiographic locations.

Altitude of the Bedrock Surface, Mineral and Missoula Counties, Montana

by

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Author's Note: This map is part of the Montana Bureau of Mines and Geology (MBMG) Ground-Water Assessment Atlas for the Lolo-Bitterroot Area ground-water characterization. It is intended to stand alone and describe a single hydrogeologic aspect of the study area, although many of the area's hydrogeologic features are interrelated. For an integrated view of the hydrogeology of the Lolo-Bitterroot Area the reader is referred to Part A (descriptive overview) and Part B (maps) of the Montana Ground-Water Assessment Atlas 4.

INTRODUCTION

The distribution of bedrock at the land surface and its position in the subsurface are important for understanding ground-water resources. Bedrock, as the term is used here, is well-cemented or indurated rock which, in Mineral and Missoula counties, consists mostly of Proterozoic metasedimentary rocks of the Belt Supergroup, sparsely distributed Paleozoic sedimentary rocks, and Cretaceous and Tertiary plutonic and metamorphic rocks. In the Lolo-Bitterroot Area, ground water is produced from the bedrock only where it is fractured; typically, unfractured bedrock is not sufficiently permeable to be considered an aquifer. In some areas, fractured bedrock is the only available aquifer either because it is the only geologic unit present or because overlying basin-fill deposits have low permeability, are unsaturated, or are too thin. Because the bedrock is usually less permeable than the overlying basin fill, it forms the base of the productive basin-fill aquifer.

This map shows the altitude above sea level of the bedrock top beneath unconsolidated surficial sediments and partially consolidated basin-fill deposits. The altitude of the contact between bedrock and basin-fill deposits was estimated from drill holes and geophysical surveys. In the Clark Fork, Ninemile, Missoula, and Seeley-Swan valleys, bedrock units beneath the basin fill are mostly the Belt Supergroup. Paleozoic sedimentary rocks crop out between the Missoula and Ninemile valleys and near Potomac. Tertiary and Cretaceous granitic intrusive rocks occur locally, especially in southern Missoula County (fig. 1). Tertiary sedimentary rock is not considered bedrock for this map because it has sufficient intergranular permeability to be an aquifer and is distinctly less lithified than the bedrock (Smith, 2006).

Development of ground-water resources in fractured bedrock aquifers increased during the 1990s as land near the perimeters of valleys was subdivided. This map is intended to help estimate the altitude of, or depth to, bedrock in areas where wells have not yet been drilled. Depths to bedrock can be calculated by subtracting a bedrock altitude derived from the map from a land-surface altitude derived from a topographic map. This map is useful for estimating drilling depths and completion levels for water wells, as an aid in planning new subdivisions or other developments relying on ground water. The map also shows areas where bedrock is near the land surface, and areas where basin-fill aquifers may be absent. Wells completed in fractured bedrock commonly produce enough water for domestic purposes, but rarely produce more than 30 gallons per minute (gpm); reported yields have a median value of 10 gpm.

DATA SOURCES AND MAP CONSTRUCTION

Data used for contouring the altitude of the bedrock surface come from descriptive lithologic logs of water wells and gravity geophysical surveys. Of the nearly 12,500 water wells with lithologic logs in the northern Lolo-Bitterroot Area, a subset of 2,800 well logs was chosen to interpret the positions of geologic units. Well logs were selected based on areal distribution, depth, lithologic detail, and locational accuracy. About 35 percent (980 of 2,800) of the well logs are interpreted to have been drilled into bedrock; these locations are shown on the map. Logs from some wells that did not penetrate bedrock also provided maximum possible bedrock altitudes. The locations of about 100 of the non-visited wells were refined by use of cadastral data; some well locations were confirmed by talking to the well owners.

Logs of drill cuttings from two uranium exploration wells, drilled to 2,515 and 2,907 ft deep, helped constrain the depth to bedrock in two areas where the depth to bedrock is greater than 2,000 ft (Norbeck, 1980). Data from these wells were used to estimate parameters necessary to model gravity surveys of the contact between weakly consolidated Tertiary strata and the highly consolidated bedrock of the Missoula Valley (Evans, 1998). Other gravity surveys include two cross sections by McMurtrey and others (1965), a regional study of the Swan Valley by Crosby (1984), and a detailed study of the East Missoula area by Nyquest (2001) (location names are in fig. 2 and studies are in fig. 3).

Depth-to-bedrock estimates derived from well-log and geophysical data were converted to altitudes above sea level by subtracting the depth values from land-surface altitudes. Land-surface altitudes at well locations were obtained from the 1:24,000-scale U.S. Geological Survey Digital Elevation Models (DEMs) using ArcInfo™ computer software. A comparison of well-location altitudes determined from topographic maps for field-confirmed well locations with those derived from the DEMs showed that most DEM-based values were within 20 ft of the field-determined values. Because of imprecision in the well-log data, contours were drawn only where multiple data points supported the contour location. Contours were drawn by hand and then digitized.

In areas of incomplete geologic mapping of Tertiary rocks and where there were no well penetrations to bedrock, the top of Belt Supergroup bedrock was mapped with long-dashed (approximate) contours. Contours based entirely on geophysical data are shown as short-dashed lines. Because data are unevenly distributed across the map and because the widths and depths of alluvial basins vary widely, contour intervals are not consistent. The contour interval is generally 200 ft in the main map; it is 100 ft in the two enlarged inset maps. The contour interval in the main parts of the Missoula and Swan valleys is 500 ft where only geophysical data were available.

Water-well driller logs and well locations are stored in the Ground-Water Information Center database at the Montana Bureau of Mines and Geology. The outcrop areas of the bedrock were modified from digital versions of geologic maps as shown in figure 3.

DISCUSSION

Regional Configuration of the Bedrock Surface

The altitude of the bedrock surface beneath basin-fill deposits was controlled by structural deformation, including faults that define some of the valley boundaries, and by erosion by streams subsequent to faulting. In most areas, available data were not sufficient to fully distinguish each process. The contours show the position of the bedrock surface, which is reasonably well constrained by drill-hole data along many of the basin margins; in these areas the position is shown with solid contours. The map is poorly constrained in most of the basin centers where few or no wells penetrate bedrock; in these areas dashed contours were used.

The bedrock surface is an unconformity between the bedrock and the overlying basin-fill units. In basin-margin areas, where Tertiary sedimentary rocks are less than a few hundred feet thick, the bedrock is an important aquifer. Bedrock aquifers are extensively used in areas along the southern and northern portions of the Missoula Valley, in the Ninemile Valley, and in the Potomac area.

Missoula Valley

The bedrock surface beneath the Missoula Valley occurs at about sea level west and northwest of the city of Missoula, and rises irregularly to the land surface at the valley margins. The irregular and complex nature of the bedrock surface is shown by well-constrained gravity surveys in the center of the Missoula Valley and in the East Missoula area (Evans, 1998; Nyquest, 2001). Movements along bounding faults have caused the basin to drop, especially along the northeast margin, and have deformed the bedrock surface. Evans (1998) interpreted the variations in the bedrock surface to be due to transpressional and transtensional vertical movements as a result of strike-slip movements along faults. The complexity shown in the southeastern portion of the Missoula Valley may be characteristic of the other, more poorly mapped portions of the basin. Because of this structural complexity, depth to bedrock is difficult to estimate in the undrilled portions of the basin.

Ninemile Valley

The geology and structure of the Ninemile Valley are poorly understood. Because of dense vegetation cover, surficial mapping of the geologic units is generalized (see McMurtrey and others, 1965; Mudge and Earhart, 1983). Available mapping indicates at least two structural basins, separated by an area where Belt Supergroup bedrock is at the land surface. Sparse subsurface data in the southeastern and northwestern portions of the valley show that part of the area is underlain by southwest-dipping bedrock surfaces. The structure of the northwestern portion of the valley is especially poorly known.

Clark Fork River Valley

The altitude of bedrock shows as much as 500 ft of variation in narrow portions of the Clark Fork River valley upstream and downstream of the Missoula Valley. Even though the present valleys are narrow, an even narrower channel cut in bedrock can typically be mapped in subsurface within the valleys. Erosion by the river was likely responsible for much of the relief on the bedrock surface. Upstream of Missoula, the map shows a 100- to 300-ft-deep incised channel that broadens and deepens towards East Missoula. Downstream of the Missoula Valley, between Alberton and Superior, a channel as much as 500 ft deep was cut into bedrock. In the lower part of the downstream reach near St. Regis, faulted and folded Tertiary sedimentary rocks are exposed along the valley margins and present in the subsurface. Understanding of the structural configuration of this part of the Clark Fork River valley is incomplete because of the sparse data.

Potomac area

The Potomac area is in a north-dipping structural valley formed by bedrock faulting on its northern margin. Lithologic logs from a few deep wells show that the Tertiary sedimentary rocks and Quaternary sediments in the basin are underlain by bedrock at depths of a few hundred to possibly as much as a thousand feet.

Seeley-Swan Valley

In the Seeley-Swan Valley, well drilling and geophysical data define the bedrock surface. The bedrock surface is determined by well-log data near the town of Seeley Lake. East of the town, the southwest-directed valley along Trail Creek has a shape that suggests an erosional origin. The valley trending northwest of Seeley Lake is a half graben with the greatest movement along the Swan Range (Mudge and Earhart, 1983). Near and north of Lindbergh and Holland Lakes, geophysical data and a few deep wells show structural complexity, with the altitude of the bedrock surface dropping to 1,500 ft above sea level. Few wells have been drilled along the valley margins north of Lindbergh Lake. The deepest part of the Swan Valley is in northern Missoula County, where bedrock is greater than 3,000 ft below sea level (Crosby, 1984). Consolidated Tertiary siltstone and carbonaceous shale have been sampled from a few of the deep wells in the area. Most of the basin fill in the Seeley-Swan Valley is thought to be Tertiary sedimentary rocks (Crosby, 1984).

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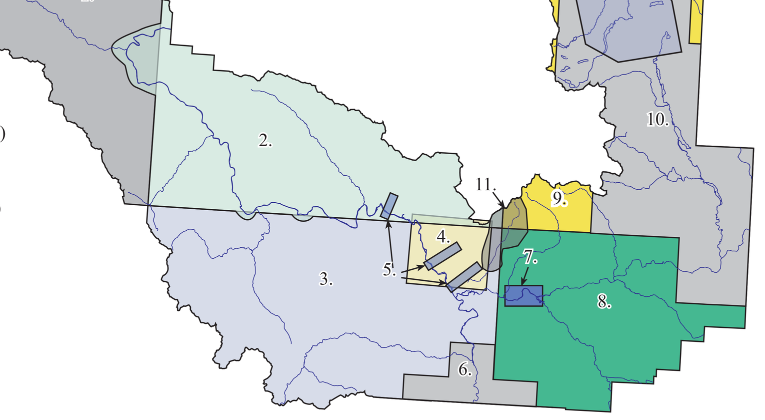

Figure 3. Index to previous maps from which contacts and subsurface data were compiled.