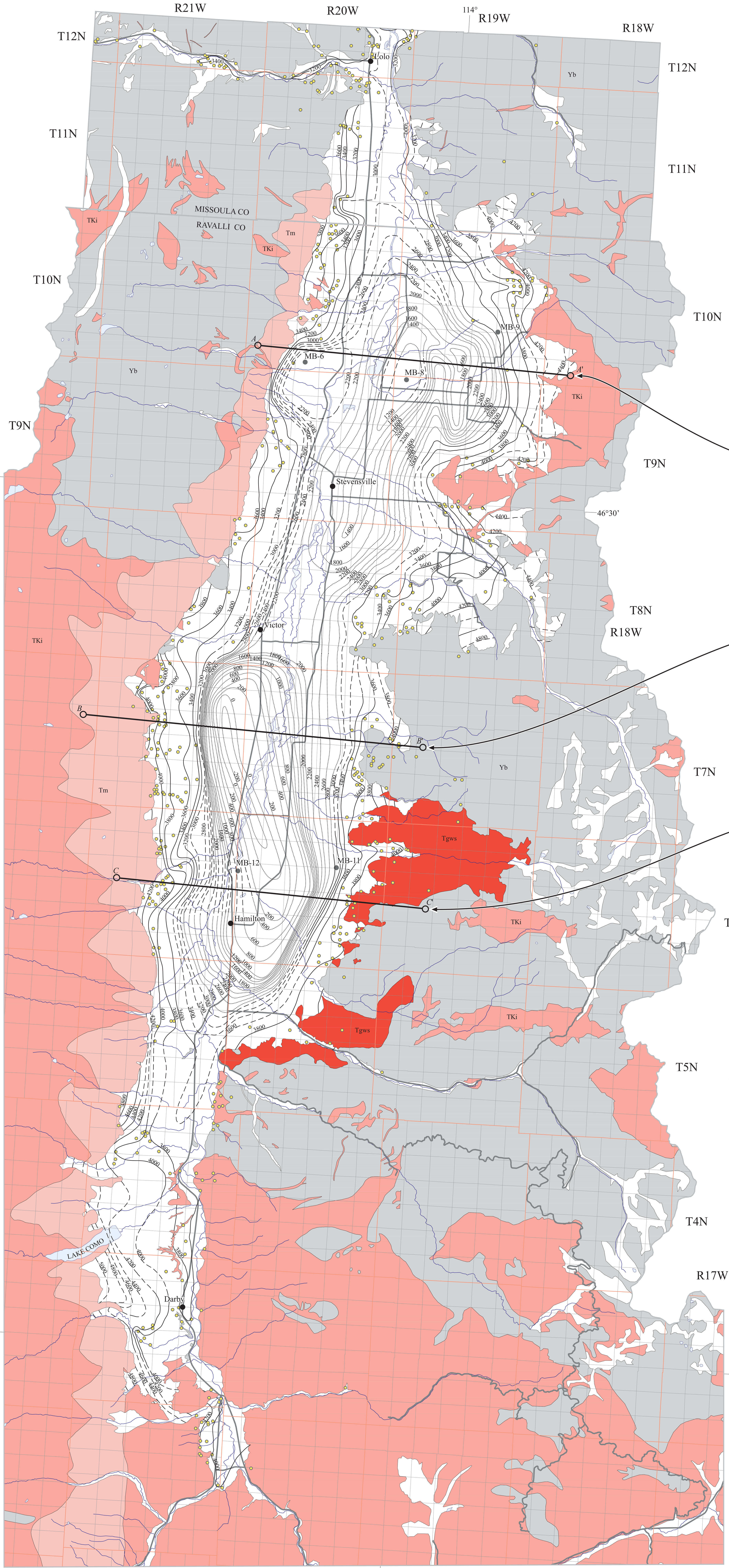

Figure 1. Altitude of bedrock in the southern part of the Lolo-Bitterroot Area.

Explanation for map

- Well that penetrates bedrock
- MB-12 Deep well from Norbeck (1980)
- 500 Contour of bedrock, altitude above mean sea level (ft)
- Approximate contour
- Inferred contour (from gravity geophysical data)
- Basin fill: Quaternary sediments and Tertiary sedimentary rocks
- Tgws Tertiary granodiorite of the Willow Creek and Skalkaho Stocks
- Tm Tertiary metamorphic rocks on Bitterroot Range front
- TKi Tertiary and Cretaceous intrusive rocks
- Yb Proterozoic Belt Supergroup rocks
- Study area boundary
- Township boundary
- Section boundary
- Major road
- Principal river or stream
- Lake or reservoir
- Active river floodplain area
- City or town

N

Scale 1:125,000

0 5 10 15 miles

Montana NAD 1983
State Plane Coordinate System

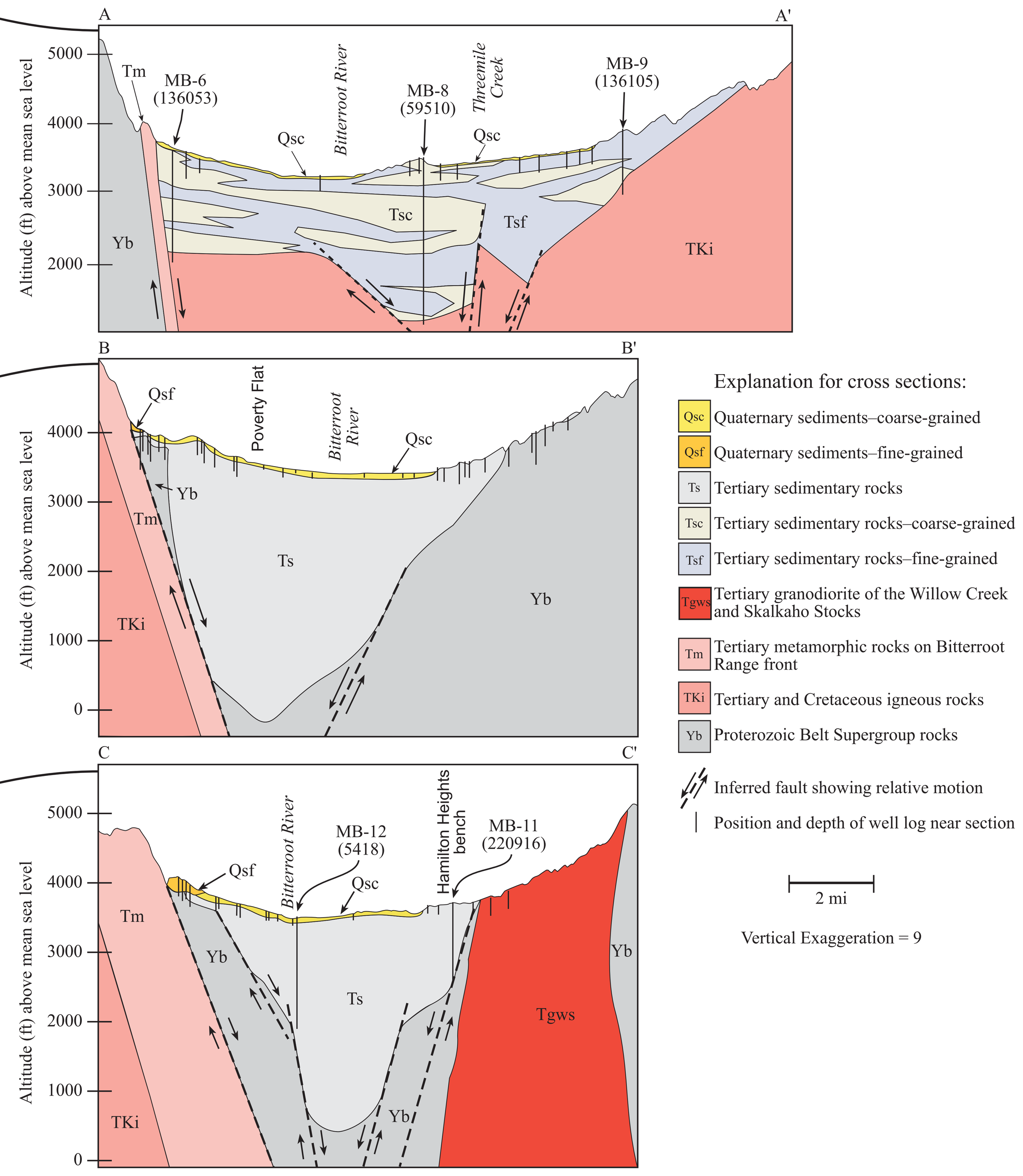

Figure 4. Cross sections showing the depth of fill in the Bitterroot Valley.

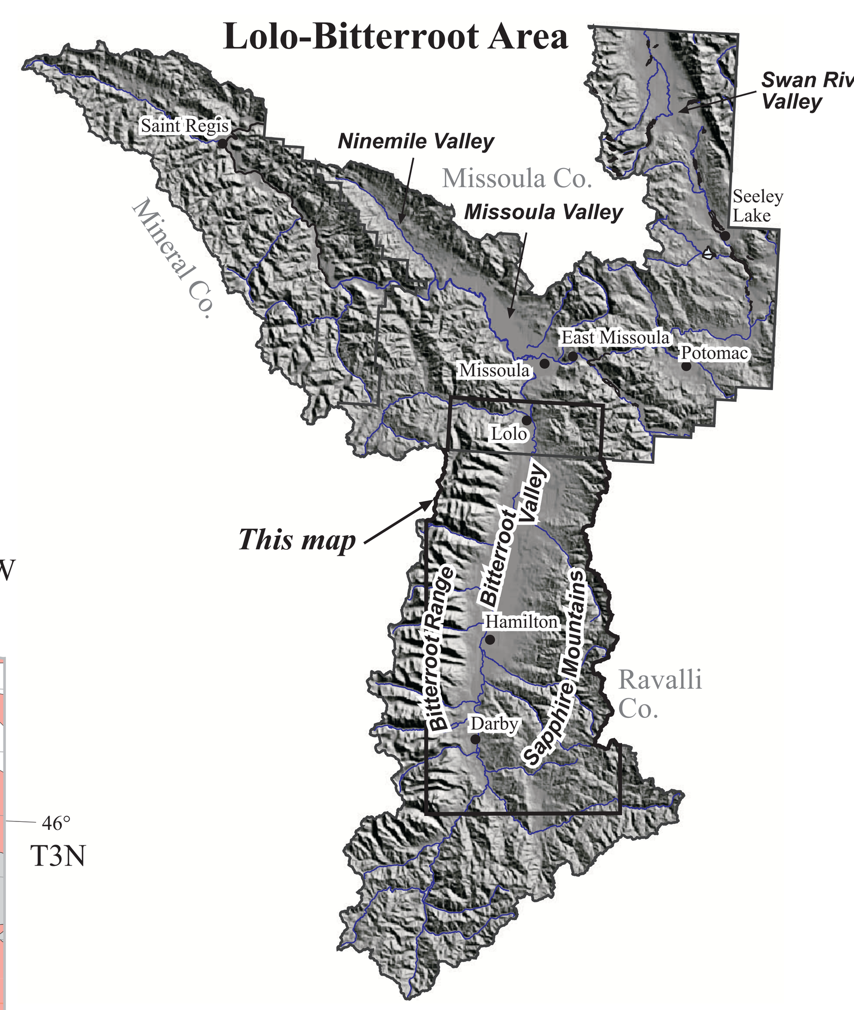

Figure 2. Index map showing the cities, drainages, and physiographic locations.

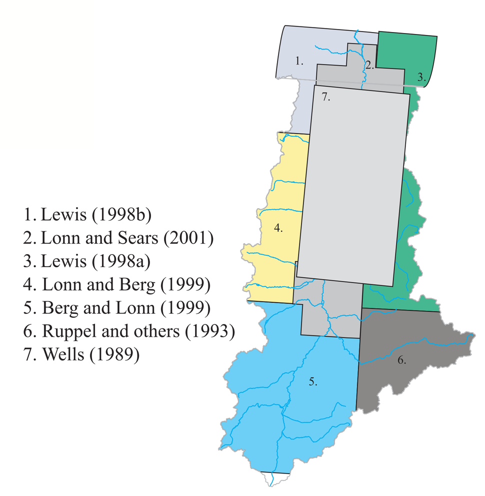

Figure 3. Index to previous maps from which contacts were compiled.

Altitude of the Bedrock Surface in the Bitterroot Valley: Missoula and Ravalli Counties, Montana

by

Larry N. Smith

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 southern Missoula and Ravalli counties consists of Proterozoic metasedimentary rocks of the Belt Supergroup 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 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 bedrock beneath unconsolidated surficial sediments and partially consolidated basin-fill deposits (fig. 1). The altitude of the contact between bedrock and basin-fill deposits was estimated from drill holes and geophysical surveys. In the Bitterroot Range and Sapphire Mountains (fig. 2) and beneath the basin fill of the Bitterroot Valley, bedrock units are Belt Supergroup, Tertiary and Cretaceous granitic intrusive rocks, and, especially in southern part of this map, Tertiary volcanic rocks. Tertiary sedimentary rock is not considered bedrock here 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 has increased during the 1990s as land near the perimeter of the Bitterroot Valley has been 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 the bedrock altitude at a location from the land-surface altitude for the same location derived from a topographic map. This map is useful for estimating drilling depths and at what levels to complete 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 thin or absent. Wells completed in fractured bedrock commonly produce enough water for domestic purposes, but rarely produce more than 20 gallons per minute (gpm); reported yields have a median value of 8 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. Aquifers were interpreted for 4,200 of the more than 15,000 water wells with lithologic logs in the southern Lolo-Bitterroot Area; the positions of geologic units were interpreted from 1,100 well logs. Well logs were selected based on areal distribution, depth, lithologic detail, and locational accuracy. About 40 percent of the wells are interpreted to have been drilled into bedrock; the locations of these are shown on the map. Logs from some wells that did not penetrate bedrock also provided maximum possible bedrock altitudes. Fifty-six of the wells drilled to bedrock (or 13 percent) were located in the field. 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 from 5 research wells, 3 in cross section A–A' north of Stevensville and 2 in cross section C–C' north of Hamilton, helped to constrain depths to bedrock in the deep portions of the basin (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 (Wells, 1989).

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. 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 40 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 were shown as short-dashed lines. 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

The contours show the position of the bedrock surface, which is reasonably well constrained by drill-hole data along many of the basin margins. Where Tertiary sedimentary rocks are less than a few hundred feet thick along the basin perimeter, the bedrock is an important aquifer. Bedrock aquifers are extensively used near the western edge of the Bitterroot Valley within a mile or two of the Bitterroot Range and along the eastern edge of the valley near bedrock outcrops. The map is poorly constrained in the central part of the valley where few or no wells penetrate bedrock.

The Bitterroot Valley was formed mostly by downdropping along a major fault system at the Bitterroot Range front, delineated by the mylonite rock "'Tm" (Hyndman, 1980; Lonn and Berg, 1999). The structure is a complex graben where slippage occurred mostly on the west side, the bedrock surface beneath the valley basically dips to the west, and the deepest parts of the basin tend to be on the west side (figs. 1, 4B). This structure is complicated by additional faults beneath the valley that show movement in both the same and the opposite directions as the west side valley-bounding fault (figs. 4A, 4C). The data suggest that there are two large sub-basins in the Bitterroot Valley, one near Hamilton and one north of Stevensville. The northern basin has multiple structurally low areas. The development of sub-basins suggests that different amounts of extension may be accommodated by cross-valley faults. However, such faulting has not been recognized in surficial geologic mapping or with subsurface data.

The northern sub-basin is illustrated along cross section A–A', where deep drilling encountered bedrock near the basin center and gravity measurements defined the shape of the basin (fig. 4A; Norbeck, 1980; Wells, 1989). North of Stevensville, the bedrock surface is as low as about 1,000 ft above sea level. The basin-fill sediment is relatively thick on the west side. The basin fill thins eastward from the valley center toward the Sapphire Mountains. The gravity data in the center of the valley suggest that the bedrock surface is disrupted by a series of north–south-trending faults (fig. 4A).

The southern sub-basin is suggested by gravity profiling along cross sections near Hamilton (figs. 1, 4B, 4C). A deep research well (MB-11) near cross section C was drilled to a bottom altitude of about 1,100 ft, but was still in Tertiary sedimentary rocks at total depth. Gravity data suggest that the bedrock surface extends below sea level along cross section B (fig. 4B). Each of the two sub-basins mapped in figure 1 have poorly constrained dimensions, but the gravity data suggest that they are separate at depth. Because of this structural complexity, depth to bedrock is difficult to estimate in the undrilled portions of the basin.

The buried bedrock surface shows about 100 ft of relief in the narrow portions of the Bitterroot Valley in the reaches north of Lolo and south of Darby. Narrow channels cut in bedrock are typical in narrow river valleys bounded by bedrock. Erosion along the river in this region, possibly during glacial times, was likely responsible for much of the relief on the bedrock surface.

ACKNOWLEDGMENTS

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