DEPARTMENT OF ENVIRONMENTAL PROTECTION
NEW JERSEY GEOLOGICAL SURVEY

BEDROCK TOPOGRAPHY MAP OF THE MILLBURN-SPRINGFIELD AREA,
ESSEX AND UNION COUNTIES, NEW JERSEY
GEOLOGIC MAP SERIES 91-4

INTRODUCTION

This map shows elevation of the bedrock surface in the area of gaps through the First and Second Watchung Mountains at Short Hills. These gaps mark the location of a sediment-filled, pre-glacial valley extending between buried valley aquifers of the central Passaic River basin, studied by Nichols (1968), Meisler (1976) and Hoffman (1989a), and the Union buried valley, traced northward into the study area by Nemickas (1974).

The possible importance to water balance of this interconnection was recognized by Hoffman (1989b), but wells and borings within the study area are few and do not provide the information necessary to evaluate conditions for water movement between well fields in the Chatham/Canoe Brook area in the central Passaic River basin and those to the southeast in the Springfield/Union area. Further detail was essential for aquifer delineation and mathematical modeling to be done as part of the Central Passaic River Bond Study (Hoffman, 1989b). This map is based on a gravity survey undertaken to provide this detail.

GENERAL GEOLOGY

The study area comprises part of the Newark Basin of New Jersey east of the Watchung syncline (fig. 1). The Passaic Formation, the oldest formation in the study area, is Late Triassic to Early Jurassic in age and consists of interbedded red shale, siltstone, sandstone and conglomerate (Lyttle and Epstein, 1987). The Orange Mountain Basalt conformably overlies the Passaic Formation and consists of Early Jurassic tholeiitic flows which form the First Watchung Mountain. The overlying Feltville Formation consists of interbedded siltstone, sandstone and laminated limestone. The Preakness Basalt conformably overlies the Feltville Formation and forms the Second Watchung Mountain. It includes at least two tholeiitic flow sheets with closely-spaced, platy columnar jointing. The Early Jurassic Towaco Formation overlies the Preakness Basalt and is composed of sandstone, siltstone and conglomerate. The study area lies within the eastern limb of the Watchung syncline (fig. 1). Bedding dips 7°-10° northwest.

The buried valley within the study area marks the pre-glacial course of the Passaic River southeastward across the Watchung ridges (Salisbury, 1902). Sediments within the valley are till, sand, silt, and gravel. The upper portion of the valley-fill was deposited as part of the late Wisconsinan terminal moraine. Deeper sediments may predate the moraine (Scott Stanford, New Jersey Geological Survey, written communication, 1989).

GRAVITY

Field Methods

Gravity observations were taken along three lines oriented northeast-southwest, parallel to strike of bedrock units, with stations located at intervals of approximately 1000 feet. A shorter interval was used in the gap area for better resolution. Line A-A', 19,100 feet long, is along Second Watchung Mountain. Line B-B', 10,950 feet long, is along the western edge of First Watchung Mountain. Line C-C', 27,800 feet long, is along the eastern edge of the mountain.

A Lacoste & Romberg Microgal gravity meter (model D25), capable of being read to the nearest 0.001 milligal (mGal) was used for gravity observations. Gravity readings were taken at bench marks, road intersections, or along roads. The accuracy of readings was maintained by taking successive observations at each station until duplication was obtained within 0.004 mGal. Station elevations were surveyed to an accuracy of ± 0.1 ft using a rod and level. Latitudes were obtained from the U.S. Geological Survey 7.5-minute Roselle and Caldwell quadrangle maps. The margin of error in latitude was 0.025 minute. The gravity observations had an accuracy of ± 0.02 mGal due to instrument, elevation and latitude inaccuracy.

Observed gravity values were based on a primary base station at Guyot Hall, Princeton University. Secondary base stations were established in the study area by tying them to the primary base station with repeated loops. The observed gravity at the Princeton base station is 980177.6 mGal (Bonini and Woollard, 1957).

Data Reduction

Gravity observations were reduced to simple Bouguer gravity anomalies using a gravity-data-reduction computer program based on formulas given by Dobrin (1976). Readings at each station were corrected for tidal and instrumental drift. The theoretical gravity at sea level for each station was determined using the International Gravity Formula of 1930 for latitude correction (Dobrin, 1976).

The effect of the elevation of the station above the sea level datum was determined by calculating the free-air and Bouguer corrections. A density of 2.67 g/cm^3, the average density of the Earth's upper crust, was used in the Bouguer correction.

Terrain corrections, which account for the deviation of topography from a horizontal surface, were calculated using the tables and graticule developed by Hammer (1939). Terrain correction factors were added to the simple Bouguer anomalies to obtain total Bouguer anomalies. These were calculated to Zone I (14,662 ft) and using a terrain density of 2.67 g/cm^3. They ranged from 0.08 mGals to 0.67 mGals.

Data Modeling

A two-dimensional, nonlinear, least-squares, interactive program was used for inverse modeling of gravity profiles to generate bedrock topography profiles. The program incorporates the Marquardt procedure (Beck and Arnold, 1977) to calculate the new parameters.

For each profile, the gravity field of the initial model was based on the bedrock elevations from wells from Nichols (1968) and Nemickas (1974) and outcrop data from Scott Stanford (N.J. Geological Survey, written communication, 1988). The models consisted of bodies representing till and basalt in A-A' and B-B', and till, sand and gravel, and shale in C-C'. Profile A-A' was modeled assuming that the basalt cropped out at the two ends of the section. The average densities used in the modeling, adapted from Dobrin (1976), Telford and others (1976), and Kodama (1983), are:

Sand and gravel	2.02 g/cm^3
Till	2.22 g/cm^3
Sedimentary rock	2.67 g/cm^3
Basalt	2.90 g/cm^3

Initial gravity values were calculated using the line integral algorithm of Talwani and others (1959). A linear regional gradient was also calculated using this model.

In the modeling process, the linear regional gravity gradient was inverted to fit the regional gravity and the depths to vertices of the bodies solved for. Interpretation of gravity anomalies is not unique. Numerous possible models can result from the same gravity profile, hence the model must be constrained. Bedrock depths, obtained from borehole logs and outcrops, and the assumed density contrasts relative to 2.67 g/cm^3 were the fixed parameters used to constrain the model.

Each vertex depth was modified interactively to adjust to differences between the calculated and observed gravity values. The interpretation was considered final when the calculated gravity values from the model fit the observed Bouguer gravity anomaly values with an error of no more than ± 0.02 mGals per station.

One of the limitations for small scale work of this method of modeling comes from an assumed two-dimensionality (Talwani and others, 1959). The two-dimensional method is a close approximation in most cases and appears to be appropriate to lines A-A' and B-B'. Line C-C' is parallel to and close by a basalt ridge, however, and the observed gravity may possibly be affected by horizontal as well as vertical differences in lithology. While distortion is probably minor, there is, unfortunately, no well or borehole available in the northeast section of profile C-C' to determine the seriousness of the problem and to constrain the model.

INTERPRETATION AND CONCLUSIONS

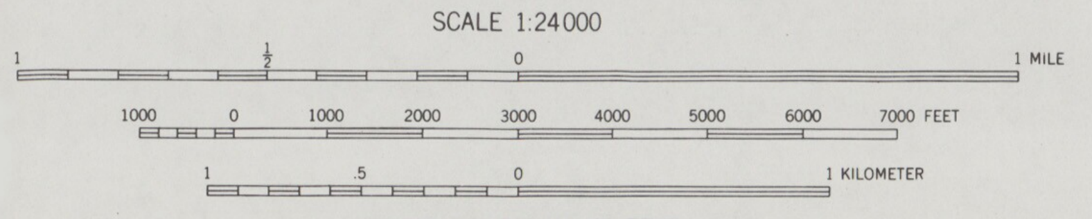
The interpreted cross sections show an irregular valley profile. The deepest part of the valley is 71 feet above sea level in profile A-A', at sea level in profile B-B', and 2 feet below sea level in profile C-C'. The valley is steeper and narrower in profile B-B' than in A-A' and C-C'. Bedrock also is close to the surface or exposed on either side of the valley near B-B'. The steep, narrow aspect of the buried valley here may be due to erosion of the Orange Mountain Basalt along a fracture or fault zone that cuts through the First Watchung Mountain.

Valley profile C-C' is broader than profiles A-A' and B-B', reflecting the generally subdued nature of the topography developed on the easily-eroded Passaic Formation. Valley profile A-A', across the Preakness Basalt, is broader than profile B-B', across the Orange Mountain basalt, probably because the Preakness is closely jointed and less resistant to erosion than the Orange Mountain Basalt. The closely-jointed nature of the Preakness Basalt can be seen in exposures along Interstate 78. The contrasting massive nature of the Orange Mountain Basalt can be seen along County 510.

The bedrock-surface elevations obtained from the gravity profile modeling were plotted with those from wells and outcrops, then contoured to obtain the bedrock-surface topography map. The map shows a pre-glacial valley trending NNW-SSE in the Millburn-Springfield area; its greatest depth is 4 feet below sea level. The valley is linear and widens considerably in the less resistant Feltville and Passaic formations. The geological and hydrogeological significance of the valley will be examined in the future phases of the Central Passaic River Basin project.

MAP EXPLANATION

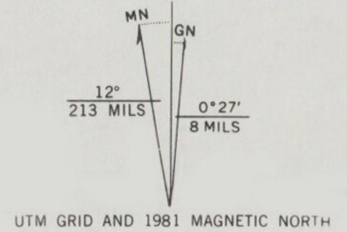
−450—	**Bedrock elevation contour** - contour interval 50 ft
x 291	**Gravity station** - with bedrock elevation
• 51	**Well or borehole** (from Nemickas, 1974) - with bedrock elevation
■ 47	**Well** (NJDEP Permit #26-16,359-4) - with bedrock elevation



CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Base from U.S. Geological Survey
Roselle Quadrangle, 1981

Gravity investigation 1987



UTM GRID AND 1981 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

BEDROCK TOPOGRAPHY MAP OF THE MILLBURN-SPRINGFIELD AREA, ESSEX AND UNION COUNTIES, NEW JERSEY

by
Suhas L. Ghatge and David W. Hall
1991

QUADRANGLE LOCATION

REFERENCES

Beck, J. W., and Arnold, K. J., 1977, Parameter estimation in engineering and science: New York, John Wiley, 501 p.

Bonini, W. E., and Woollard, G. P., 1957, Observational accuracy of high-range geodetic type Worden gravimeters: American Geophysical Union Transactions, v. 38, p. 147-155.

Dobrin, M. B., 1976, Introduction to geophysical prospecting (3rd ed.): New York, McGraw-Hill, 630 p.

Hammer, Sigmund, 1939, Terrain corrections for gravimeter stations: Geophysics, v. 4, p. 184-194.

Hoffman, J. L., 1989a, Simulated drawdowns, 1972-1995, in the Pleistocene buried-valley aquifers in southwestern Essex and southeastern Morris Counties, New Jersey: New Jersey Geological Survey Open-File Report 89-1, 22 p.

Hoffman, J. L., 1989b, Plan of study for the central Passaic River basin hydrogeologic investigation: New Jersey Geological Survey Open-file Report 88-4, 22 p.

Kodama, P. K., 1983, Magnetic and gravity evidence for a subsurface connection between the Palisades sill and the Ladentown basalts: Geological Society of America Bulletin, v. 94, p. 151-158.

Lyttle, P. T., and Epstein, J. B., 1987, Geologic map of the Newark 1° x 2° quadrangle, New Jersey: U.S. Geological Survey Miscellaneous Investigations Series Map I-1715, scale 1:250,000.

Nemickas, Bronius, 1974, Bedrock topography and thickness of Pleistocene deposits in Union County and adjacent areas, New Jersey: U. S. Geological Survey Miscellaneous Geologic Investigations Map I-795.

Nichols, W. D., 1968, Bedrock topography of eastern Morris and western Essex Counties, New Jersey: U. S. Geological Survey Geologic Investigations Map I-549, scale 1:24,000.

Olsen, P. E., 1980, The latest Triassic and Early Jurassic formations of the Newark Basin (Eastern North America, Newark Supergroup): stratigraphy, structure, and correlation: The Bulletin, New Jersey Academy of Science, v. 25, no. 2, p. 25-51.

Salisbury, R. D., 1902, The glacial geology of New Jersey: New Jersey Geological Survey Final Report of the State Geologist, v. 5, 802 p.

Talwani, Manik, Worzel, J. L., and Landisman, M., 1959, Rapid gravity computations for two-dimensional bodies with application to the Mendocino submarine fracture zones: Journal of Geophysical Research, v. 64, p. 49-59.

Telford, W. M., Geldart, L. P., Sheriff, R. E., and Keys, D. A., 1976, Applied Geophysics: Cambridge, England, Cambridge University Press.

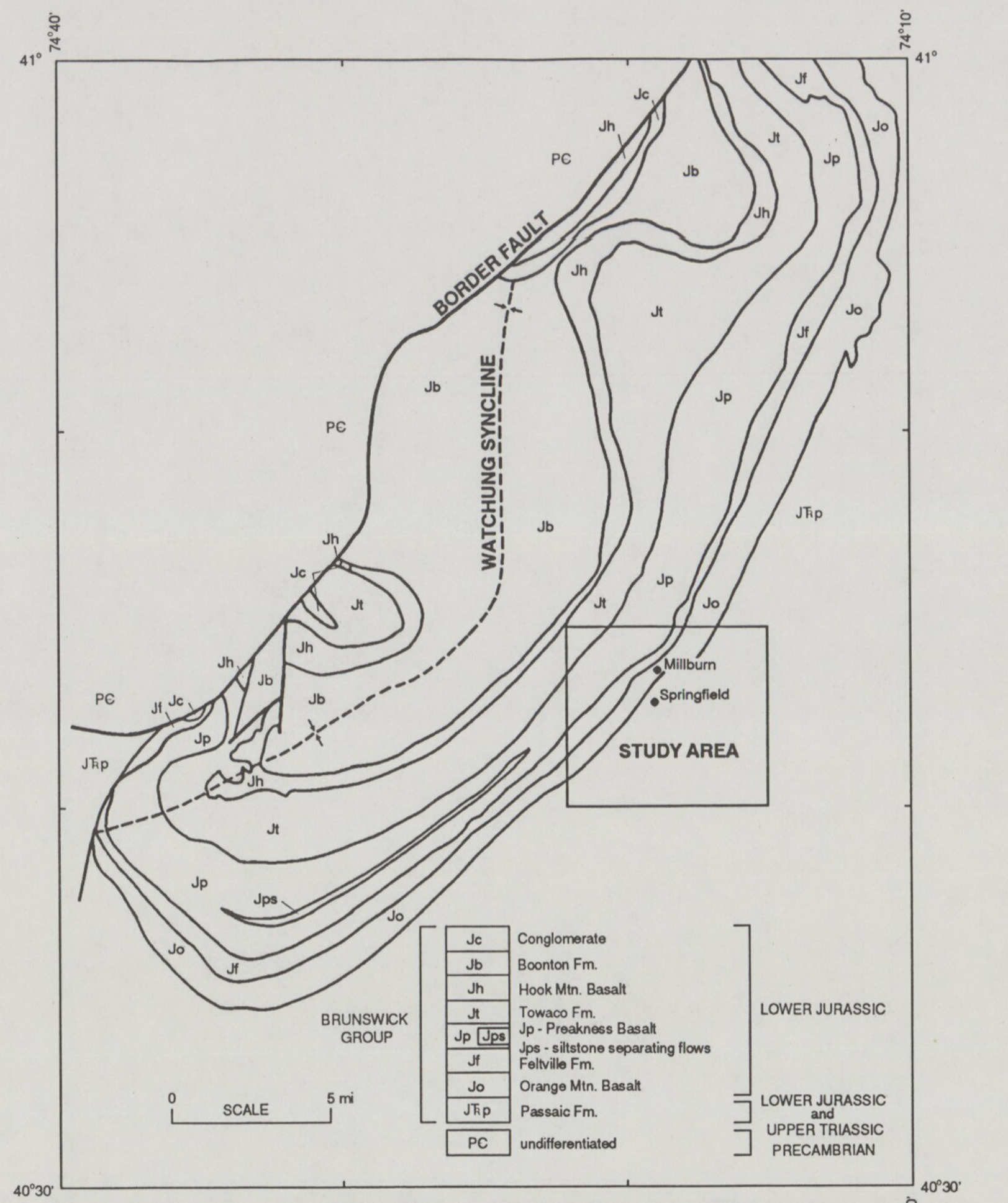


Figure 1. Geology of Newark Basin showing study area. Modified from Lyttle and Epstein, 1987.