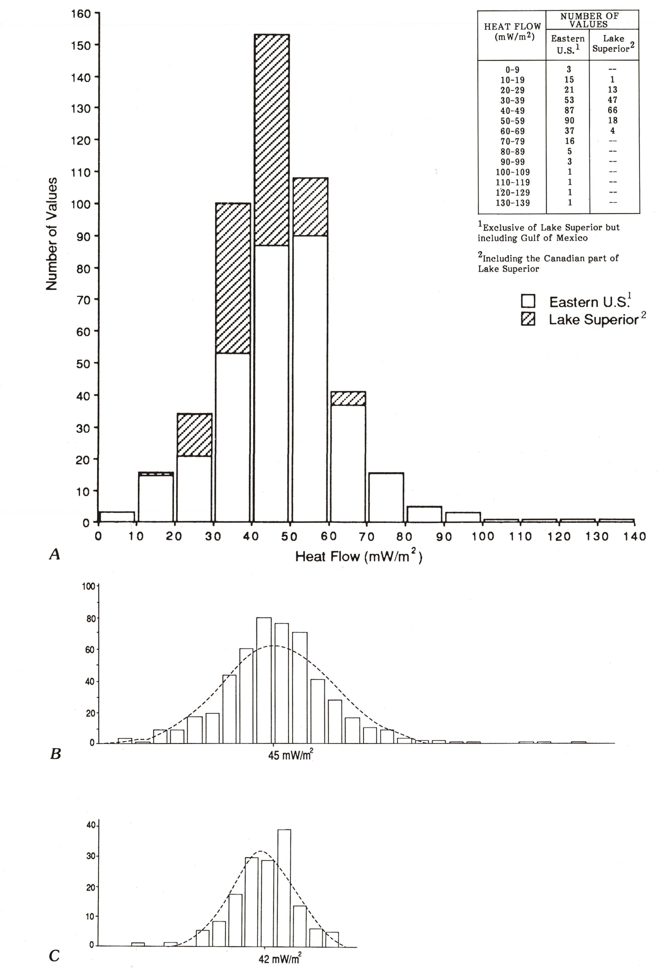

Figure 2.--Frequency distribution of heat-flow values (in mW/m^2) in the eastern United States and selected adjacent areas. *A*, All values in catalog; Lake Superior values are shaded. Classes are 10 mW/m^2. Left column of table lists numbers of values for the eastern United States and Gulf of Mexico exclusive of Lake Superior; right column gives numbers of values from both the U.S. and Canadian parts of Lake Superior. *B*, All values in catalog, 5 mW/m^2 classes. Gaussian curve for values is shown. Mean=46; median=45; skewness=+0.87; kurtosis=+0.38. *C*, Heat-flow values and Gaussian curve for Lake Superior. Mean=41; median=42; skewness=-0.67; kurtosis=+0.17.

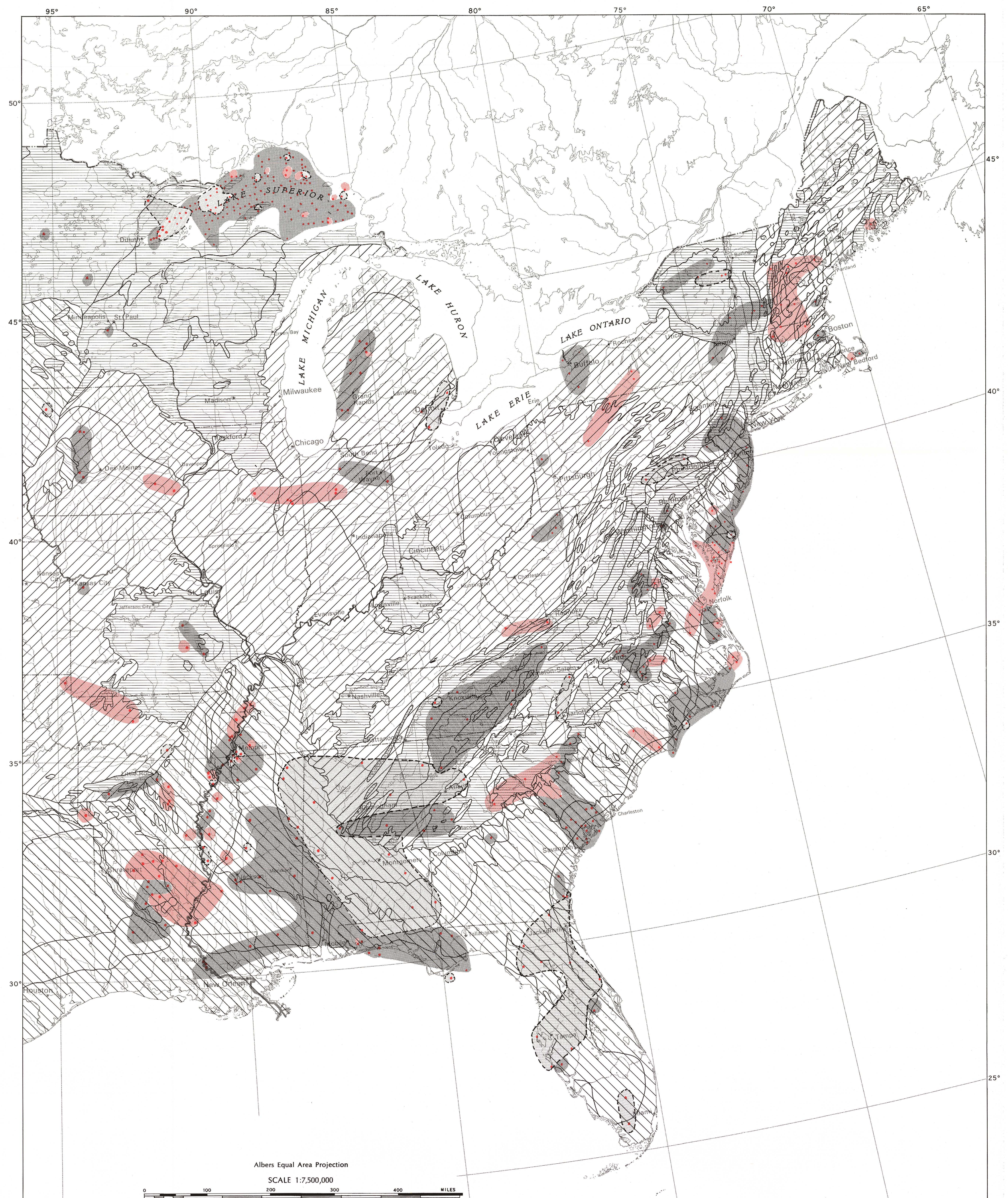

Figure 3.--Geologic map of the eastern United States showing the distribution of heat-flow values. Heat-flow levels as for figure 1. Geologic map generalized from D.M. Kinney (*in* U.S. Geological Survey, 1970, p. 75).

← EXPLANATION

AGE AND GENERAL DISTRIBUTION OF ROCK UNITS

Cenozoic and Mesozoic rocks--Sedimentary units of Holocene through Cretaceous age occupy Atlantic and Gulf Coastal Plains; Cretaceous sedimentary rocks also are found southwest of Laurentian Upland (fig. 1). Some granitic intrusions of Tertiary and Cretaceous age present in eastern United States but not distinguished. Jurassic and Triassic sedimentary and igneous rocks present in narrow, fault-bounded basins within Piedmont physiographic province and buried beneath Coastal Plain (fig. 1)

Upper and middle Paleozoic rocks--Sedimentary rocks of Pennsylvanian through Silurian age occupy most midcontinental basins and plateau areas; north of about lat 40° N., mostly covered by glacial material. Permian rocks present only in some parts of Pennsylvania, West Virginia, and Virginia. Most of New England underlain by Devonian and Silurian rocks. Large intrusives, chiefly granitic, mainly Paleozoic, scattered throughout Piedmont and New England

Lower Paleozoic and Precambrian rocks--Sedimentary rocks of Ordovician and Cambrian age in midcontinental arches underlying the western edge of folded Appalachians (fig. 1) and eastern Maine. Lower Paleozoic and Precambrian metamorphic and igneous rocks compose most of the Piedmont and Blue Ridge physiographic provinces, Adirondack Mountains, Laurentian Upland, and core of Ozark Plateau (fig. 1)

HEAT FLOW LEVELS
(Values in milliwatts per square meter (mW/m^2))

More than 54

35-54

Less than 35

Heat-flow data point

EXPLANATION →

TECTONIC UNITS

DEFORMED ROCKS--Appalachian orogen (Alabama to Maine), consisting of intensely folded and locally metamorphosed rocks of Paleozoic to Late Precambrian age, massifs of Late to Early Precambrian metamorphic and plutonic rocks, and moderately deformed rocks of Jurassic age. Precambrian massifs also form Adirondack Mountains and Laurentian Upland (fig. 1). Folded rocks of Middle to Early Paleozoic age underlie Ouachita Mountains (fig. 1). Western boundary of Appalachian orogen and northern boundary of Ouachita Mountains foldbelt are farther north and west, respectively, than shown on National Atlas map (U.S. Geological Survey, 1970)

RELATIVELY UNDEFORMED ROCKS

Continental margin, consisting mainly of unconsolidated, shallowly dipping, Holocene to Cretaceous Coastal Plain deposits overlying Paleozoic and Precambrian Piedmont rocks of Appalachian orogen; discontinuous Mesozoic grabens also present.

Continental interior, underlain by regionally warped sedimentary rocks that overlie chiefly Precambrian basement rocks

Axis of closely compressed anticline

Axis of broad anticline or anticlinorium

Axis of syncline

Dip of strata in homocline

Thrust fault--Barbs on upthrown side

Normal fault--Hachures on downthrown side

Concealed fault

Inferred fault

Structure contour--Shown on surface of basement rocks. Contour interval is 1,000 m (3,280 ft). Zero contour on Paleozoic and Precambrian basement is just seaward of inner edge of Atlantic and Gulf Coastal Plains. In middle part of Mississippi River valley, contours on both Paleozoic and Precambrian surfaces are shown

Salt diapir--Represent areas of high conductivity

HEAT FLOW LEVELS
(Values in milliwatts per square meter (mW/m^2))

More than 54

35-54

Less than 35

Heat-flow data point

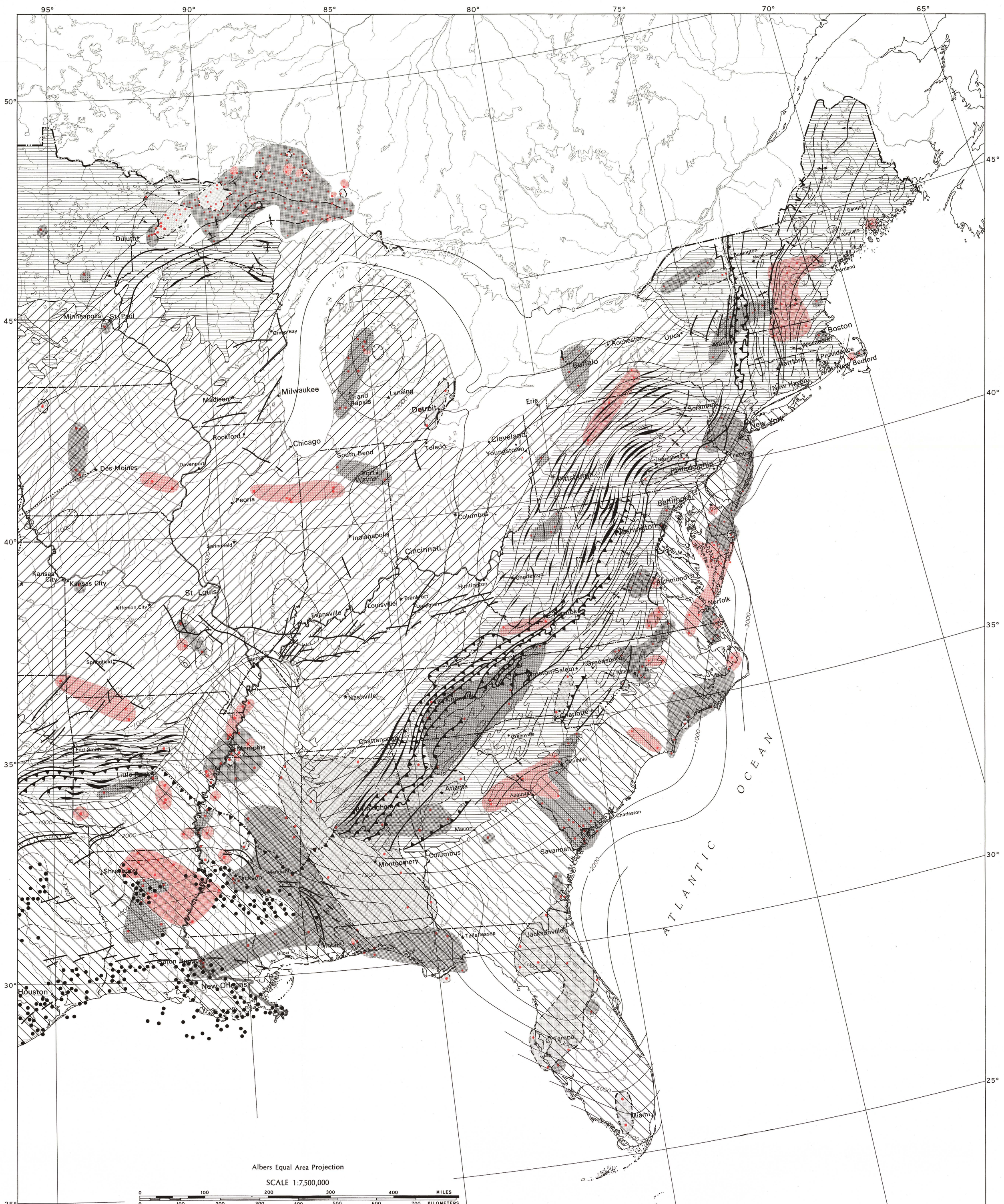

Figure 4.--Tectonic map of the eastern United States showing the distribution of heat-flow values. Heat-flow levels as for figure 1. Tectonic map generalized from P.B. King (*in* U.S. Geological Survey, 1970, p. 71).

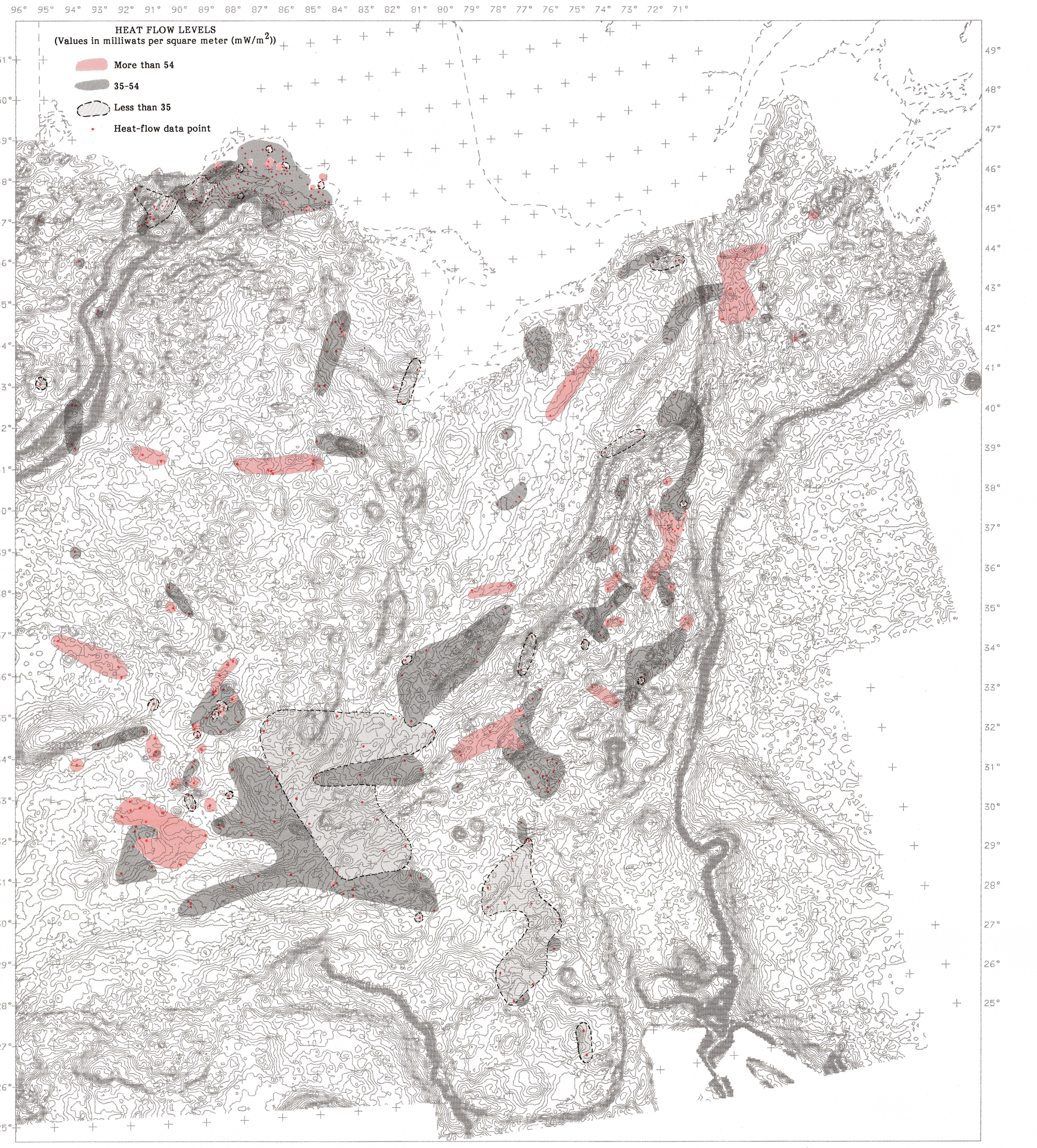

Figure 5.--Bouguer gravity anomaly map of the eastern United States showing the distribution of heat-flow values. Heat-flow levels as for figure 1. Base map prepared by S.L. Snyder (USGS) from digital data provided by the USGS and the Geological Survey of Canada (Godson, 1986; Godson and Scheibe, 1982); for larger scale, see Society of Exploration Geophysicists (1982). Contour interval 5 milligals.

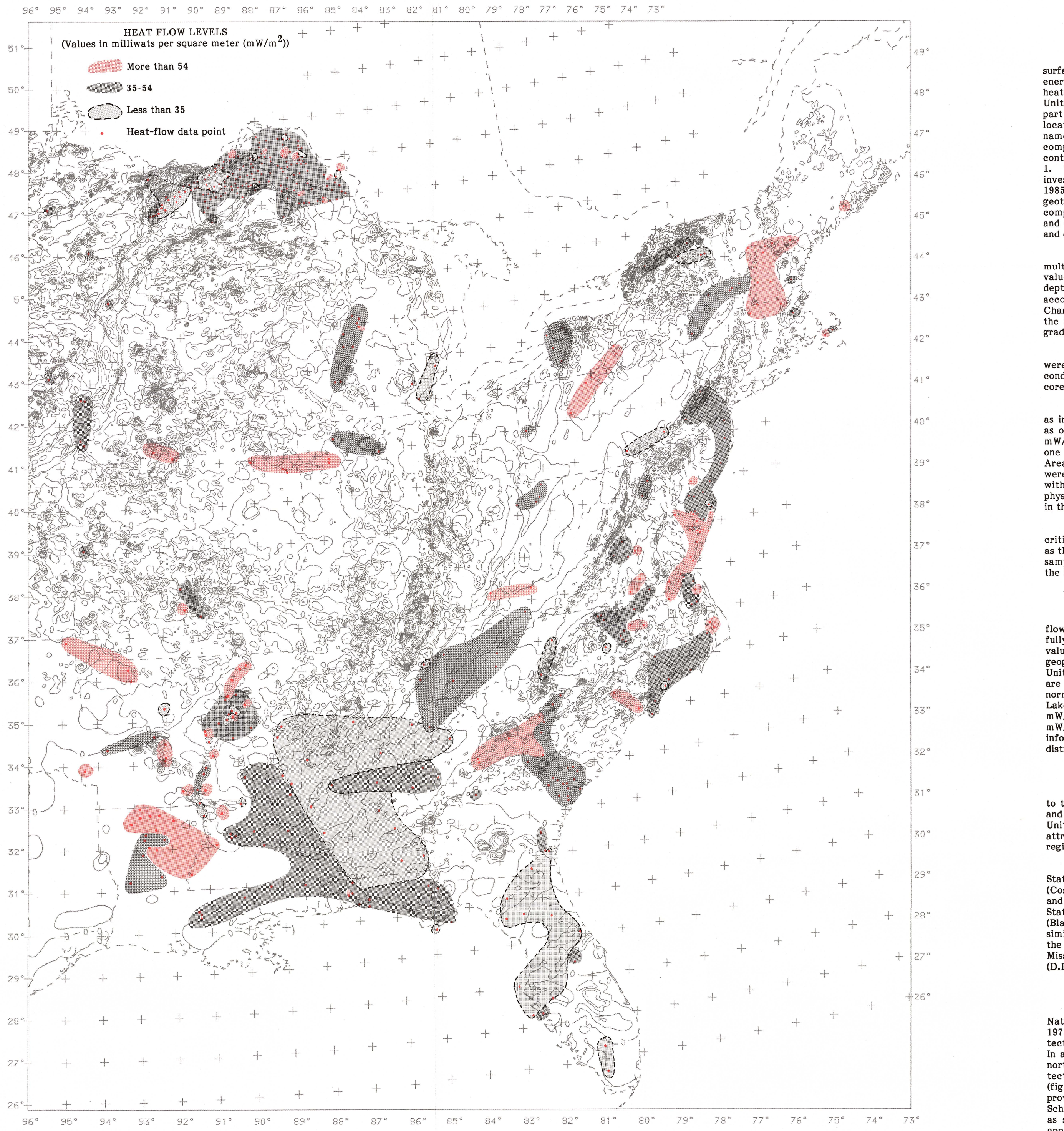

Figure 6.--Magnetic anomaly map of the eastern United States showing the distribution of heat-flow values. Heat-flow levels as for figure 1. Magnetic map prepared from digital data provided by the USGS and the Geological Survey of Canada (see Godson, 1986; Godson and Scheibe, 1982); for larger scale and smaller contour interval, see Zeitz (1982). Contour interval 250 nanoteslas.

THE HEAT FLOW MAP AND CATALOG

Heat flow is the rate of transport of thermal energy to the Earth's surface from the interior. Heat flow is measured in units of thermal energy per time per area. The 1:2,500,000-scale map (fig. 1) shows 467 heat-flow values in milliwatts per square meter (mW/m^2) for the eastern United States (area mainly east of the Mississippi River) and the Canadian part of Lake Superior; the accompanying catalog (table 1) gives depths, location (latitude, longitude, state, county, and 7.5-minute quadrangle name), and references for the values. The catalog, which is available on computer diskette in ASCII from the U.S. Geological Survey (USGS)[1], also contains 16 values from the Gulf of Mexico that are not shown on figure 1. The heat-flow data were compiled during a U.S. Geological Survey investigation of possible Cenozoic intrusions (McCartan and Gettings, 1985). The map and catalog were designed as source references for other geothermal and crustal studies. The most extensive previously published compilations of heat-flow data for the eastern United States are by Jessop and others (1975), Grim (1976; derived from Jessop and others, 1975), Sass and others (1976, 1981), and Costain and others (1986).

Most land-based heat-flow values in this study were derived by multiplying a geothermal gradient, measured in a drill hole, by conductivity values from one or more rock samples from the same drill hole. Drill-hole depths and rock conductivity values are given in some of the references accompanying table 1. The known exceptions are 15 estimates in the Charleston, S.C., area that were made by using the conductivity value from the Clubhouse Crossroads corehole (Sass and Ziagos, 1977) and geothermal gradients from other holes (M.E. Gettings, USGS, 1986, written commun.).

Heat-flow values from lake bottoms and the 16 Gulf of Mexico sites were determined from thermal gradients measured in drill holes and conductivities were measured by the needle probe method on sediment cores (Steinhart and others, 1969; Epp and others, 1970).

Heat-flow values are shown on the map in three ways: 1) by number as individual values, 2) by symbol as one of seven levels, and 3) by shading as one of three levels (light gray, less than 35 mW/m^2; dark gray, 35-54 mW/m^2; and red, more than 54 mW/m^2). The value 42 mW/m^2 is equal to one heat-flow unit (HFU, equal to $1x10^{-6}$ $cal/cm^2/sec$) of other authors. Areas with insufficient data are blank. The extents of the shaded areas were determined partly by comparing the distribution of heat-flow values with several indicators of regional structure, including geologic, tectonic, physiographic, and Bouguer gravity anomaly and magnetic anomaly patterns in the eastern United States.

The heat-flow values have been accepted as published without critical evaluation. Reliability of the values is dependent on factors such as the depths of the thermal gradient measurement, the homogeneity of the samples for which thermal conductivity was measured, and the precision of the instruments used (Griffin and others, 1969, 1977; Lee and Uyeda, 1965).

Distribution of heat-flow values

The heat-flow values range from 4 to 131 mW/m^2; because the heat-flow values are the result of various areal and topical studies, they do not fully represent the eastern United States. For example, 159 of the 483 values are from Lake Superior; other clusters of values represent smaller geographic areas. The distribution of heat-flow values in the eastern United States and adjacent areas is slightly leptokurtic; that is, the values are more closely grouped around the mean than they would be in a true normal (Gaussian) distribution (figs. 2*A* and 2*B*). The same is true for the Lake Superior heat-flow values (fig. 2*C*). The median of all the values is 45 mW/m^2, whereas the median of the Lake Superior distribution is 42 mW/m^2. The statistical moments are valuable as descriptors and as basic information for future studies even though the geological basis for the distributions is not yet well understood.

Origin of heat flow in the eastern United States

The production of heat within the mantle and crust and its transfer to the Earth's surface were discussed at length by Birch and others (1968) and Roy and others (1968). Regional heat-flow patterns in the eastern United States were analyzed by Diment and others (1972). Their study attributed low regional heat flow to crustal thickening; conversely, high regional heat flow generally was found to be coincident with thinner crust.

Several of the local positive thermal anomalies in the eastern United States occur over synmetamorphic and postmetamorphic granitic bodies (Costain and others, 1986) or salt intrusions (Jacoby and Paul, 1974; Smith and Dees, 1982). High heat flow has been noted in the western United States over rocks inferred to contain incompletely cooled plutons (Blackwell, 1971; Sass and others, 1971; Lachenbruch and Sass, 1977), and a similar relationship is postulated at certain places in the east, such as in the Charleston, S.C., area (McCartan and Gettings, 1985), Jackson Dome, Miss. (McCartan, 1986, unpublished data), and the New Madrid, Mo., area (D.L. Smith, University of Florida, 1986, written commun.).

Comparison of heat flow with geologic and geophysical patterns

The geologic (fig. 3) and tectonic (fig. 4) base maps are from the National Atlas of the United States of America (U.S. Geological Survey, 1970, p. 71 and 75). All original contacts are shown, but the geologic and tectonic units have been generalized for comparison with heat-flow data. In addition, the thrust-faulted areas west of the Appalachian fold belt and north of the Ouachita Mountains were included with those adjacent tectonic features (fig. 4). Gravity-anomaly (fig. 5) and magnetic-anomaly (fig. 6) base maps were produced by S.L. Snyder (USGS) from digital data provided by the USGS and the Canadian Geological Survey (Godson and Scheibe, 1982; Godson, 1986). Heat-flow localities are shown on figures 3-6 as solid red dots. The three levels of heat-flow values on figure 1 also appear on figures 3-6. The 1:7,500,000-scale maps are intended to encourage further study into the correlation between heat flow and geological and geophysical features in the eastern United States.

[1] McCartan, Lucy, and Architzel, R.J., 1988, Catalog of heat-flow values and other pertinent data from the eastern United States and selected adjacent areas, in ASCII on IBM-compatible 5¼-inch diskette; supplement to U.S. Geological Survey Miscellaneous Field Studies Map MF-2057: U.S. Geological Survey Open-File Report 88-681 [Available from U.S. Geological Survey Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225].

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M.E. Gettings (USGS), D.L. Smith (University of Florida), R.F. Roy (University of Texas, El Paso), R.H. Godson (USGS), and the Geological Survey of Canada contributed unpublished data. Gettings also statistically analyzed the heat-flow data. S.L. Snyder (USGS) manipulated processed digital data to produce the 1:7,500,000-scale base maps. M.C. Guffanti (USGS) helped evaluate the distribution of heat-flow data.

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HEAT FLOW MAP OF THE EASTERN UNITED STATES

By
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1988