Massachusetts Geological Survey
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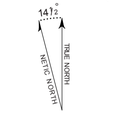
MGS Miscellaneous Map M-13-05
Massachusetts Geothermal Energy Project:
Temperature Map at 4 Km Depth
2013

Shaded relief (5-m resolution) is a mosaic of digital terrain models (DTMs) derived from digital orthoimages available from the Massachusetts Office of Geographic Information (MassGIS; www.mass.gov/mgis); geology modified from Zen et al. (1983).

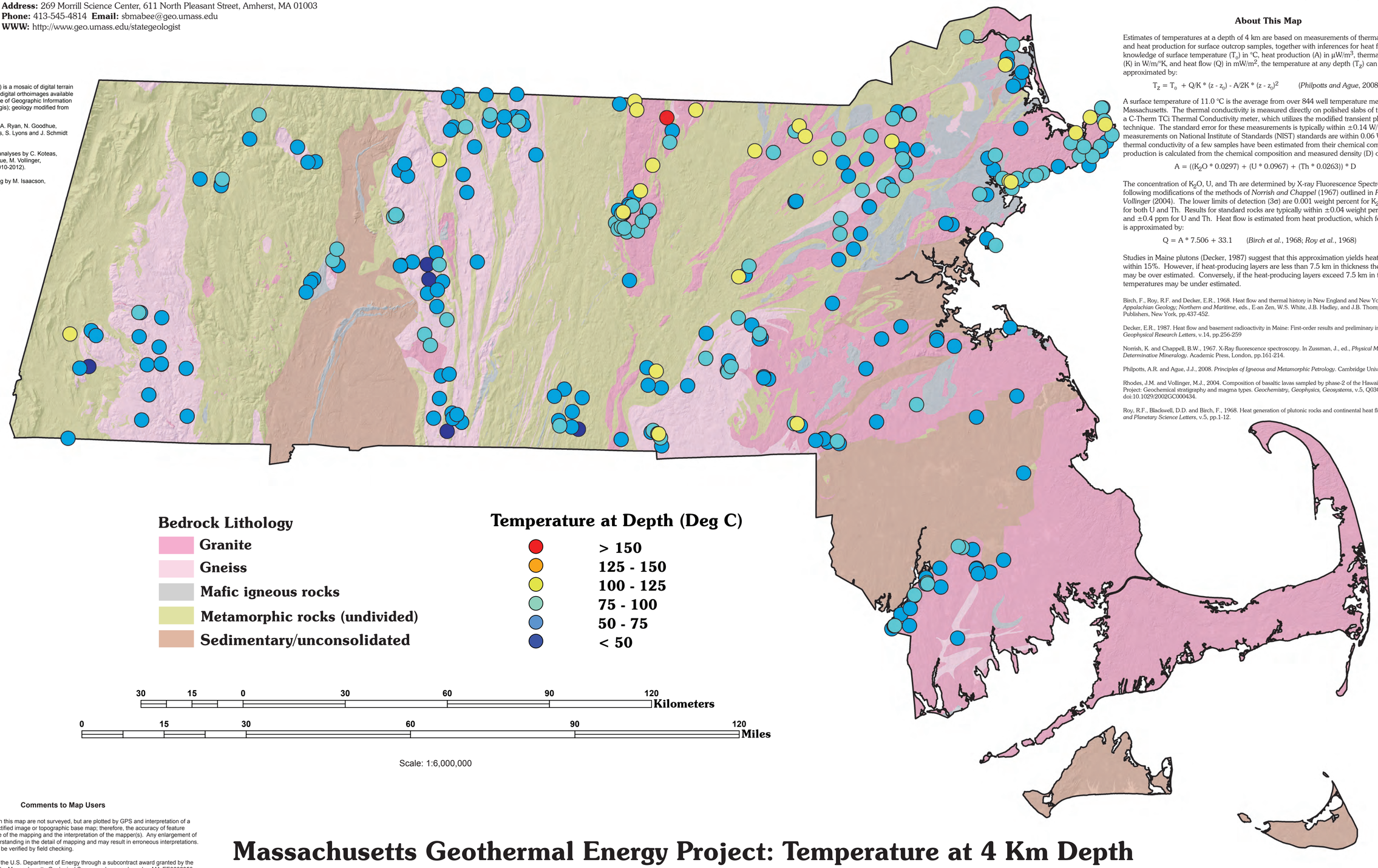
Field sampling by C. Koteas, A. Ryan, N. Goodhue, F. Iwanik, R. Weiss, S. Adams, S. Lyons and J. Schmidt (2010-2012).

Sample preparation and lab analyses by C. Koteas, R. Weiss, S. Adams, C. League, M. Vollinger, M. Mnich and B. Leighton (2010-2012).

Digtial cartography and editing by M. Isaacson, M. Rhodes, S. Mabee (2013)



APPROXIMATE MEAN DECLINATION, 2013



Scale: 1:6,000,000

About This Map

Estimates of temperatures at a depth of 4 km are based on measurements of thermal conductivity and heat production for surface outcrop samples, together with inferences for heat flow. With a knowledge of surface temperature (T_0) in °C, heat production (A) in $\mu W/m^3$, thermal conductivity (K) in W/m/°K, and heat flow (Q) in mW/m^2, the temperature at any depth (T_z) can be approximated by:

$$T_z = T_0 + Q/K * (z - z_0) - A/2K * (z - z_0)^2$$ (*Philpotts and Ague*, 2008)

A surface temperature of 11.0 °C is the average from over 844 well temperature measurements in Massachusetts. The thermal conductivity is measured directly on polished slabs of the sample using a C-Therm TCi Thermal Conductivity meter, which utilizes the modified transient plane source technique. The standard error for these measurements is typically within ±0.14 W/m/°K (~5%) and measurements on National Institute of Standards (NIST) standards are within 0.06 W/m/°K. The thermal conductivity of a few samples have been estimated from their chemical composition. Heat production is calculated from the chemical composition and measured density (D) of the samples.

$$A = ((K_2O * 0.0297) + (U * 0.0967) + (Th * 0.0263)) * D$$

The concentration of K_2O, U, and Th are determined by X-ray Fluorescence Spectroscopy (XRF) following modifications of the methods of *Norrish and Chappel* (1967) outlined in *Rhodes and Vollinger* (2004). The lower limits of detection (3σ) are 0.001 weight percent for K_2O and 0.3 ppm for both U and Th. Results for standard rocks are typically within ±0.04 weight percent for K_2O and ±0.4 ppm for U and Th. Heat flow is estimated from heat production, which for New England is approximated by:

$$Q = A * 7.506 + 33.1$$ (*Birch et al.*, 1968; *Roy et al.*, 1968)

Studies in Maine plutons (Decker, 1987) suggest that this approximation yields heat flow values within 15%. However, if heat-producing layers are less than 7.5 km in thickness their temperatures may be over estimated. Conversely, if the heat-producing layers exceed 7.5 km in thickness their temperatures may be under estimated.

Birch, F., Roy, R.F. and Decker, E.R., 1968. Heat flow and thermal history in New England and New York. In *Studies in Appalachian Geology; Northern and Maritime*, eds., E-an Zen, W.S. White, J.B. Hadley, and J.B. Thompson, Interscience Publishers, New York, pp.437-452.

Decker, E.R., 1987. Heat flow and basement radioactivity in Maine: First-order results and preliminary interpretations, *Geophysical Research Letters*, v.14, pp.256-259

Norrish, K. and Chappell, B.W., 1967. X-Ray fluorescence spectroscopy. In Zussman, J., ed., *Physical Methods in Determinative Mineralogy*. Academic Press, London, pp.161-214.

Philpotts, A.R. and Ague, J.J., 2008. *Principles of Igneous and Metamorphic Petrology*. Cambridge University Press, pp.6-13.

Rhodes, J.M. and Vollinger, M.J., 2004. Composition of basaltic lavas sampled by phase-2 of the Hawaii Scientific Drilling Project: Geochemical stratigraphy and magma types. *Geochemistry, Geophysics, Geosystems*, v.5, Q03G13, doi:10.1029/2002GC000434.

Roy, R.F., Blackwell, D.D. and Birch, F., 1968. Heat generation of plutonic rocks and continental heat flow provinces. *Earth and Planetary Science Letters*, v.5, pp.1-12.

Comments to Map Users

Locations of features shown on this map are not surveyed, but are plotted by GPS and interpretation of a given feature on to an orthorectified image or topographic base map; therefore, the accuracy of feature locations depends on the scale of the mapping and the interpretation of the mapper(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site specific conditions should be verified by field checking.

This project was supported by the U.S. Department of Energy through a subcontract award granted by the Arizona Geological Survey to the Massachusetts Geological Survey under award number MA-EE0002850. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing official policies, either expressed or implied, of the U.S. Government, Commonwealth of Masschusetts, the University of Massachusetts or Massachusetts Geological Survey.

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This map was produced on request directly from digital files (PDF format) on an electronic plotter.

A digital copy of this map (PDF format) is available at http://www.geo.umass.edu/stategeologist.

Massachusetts Geothermal Energy Project: Temperature at 4 Km Depth

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