GEOLOGIC AND GEOPHYSICAL STUDIES IN THE MONT DORE GEOTHERMAL AREA, FRANCE

Jacques Varet, Andre Gerard, Laurent Stieltjes and Wendell Duffield*

B.R.G.M., Orleans, France *U. S. Geological Survey, Menlo Park CA 94025

ABSTRACT

Mont Dore Volcano in central France grew during two periods since about 4 m.y. B.P. The older period lasted from about 4 m.y. to 1.8 m.y. B.P. and was highlighted by the formation of a caldera, apparently in response to the eruption of a pumiceous, rhyolite ash flow. The younger period lasted from 0.8 to 0.25 m.y. B.P. and was characterized by the emplacement of domes, flows, and associated pyroclastic debris of intermediate composition, principally along the east and south margins of the caldera.

A Bouguer gravity low of about 20 milligals suggests that the caldera is filled with ≤1 km of low density rocks, and a similar depth of caldera fill is suggested by geoelectric soundings. Several thermal springs within the caldera are surface evidence of convecting geothermal fluids that may be driven by residual thermal energy associated with magmatism of Mont Dore.

INTRODUCTION

Tertiary and Quaternary volcanic rocks partly veneer a basement complex of Paleozoic crystalline rocks in central France (fig. 1). Most of the volcanic sequence consists of mafic lava flows that were erupted from monogenetic volcanoes or fissures; such volcanism is judged to have little potential as a heat source for geothermal systems, because associated crustal magma reservoirs were probably never well developed. The Mont Dore area, however, is the site of a large polygenetic volcano that erupted basalt, lavas of intermediate compositions and rhyolite during late Tertiary and early Quaternary time. Moreover, many thermal springs occur within and adjacent to this volcano. Accordingly, the Mont Dore area was selected for assessment on the assumption that a magma-related geothermal system exists within and/or beneath the volcano. Researchers at several French agencies and universities began a comprehensive program of study in 1978; the Bureau de Recherches Geologiques et Minieres (BRGM) plays the lead role. We herein present a progress report. Some conclusions and interpretations may be modified as work progresses, but we expect no major changes in our present understanding of the geothermal system. An exploration well is anticipated within a year or two, when the ongoing earth science studies have pinpointed a favorable drilling target.

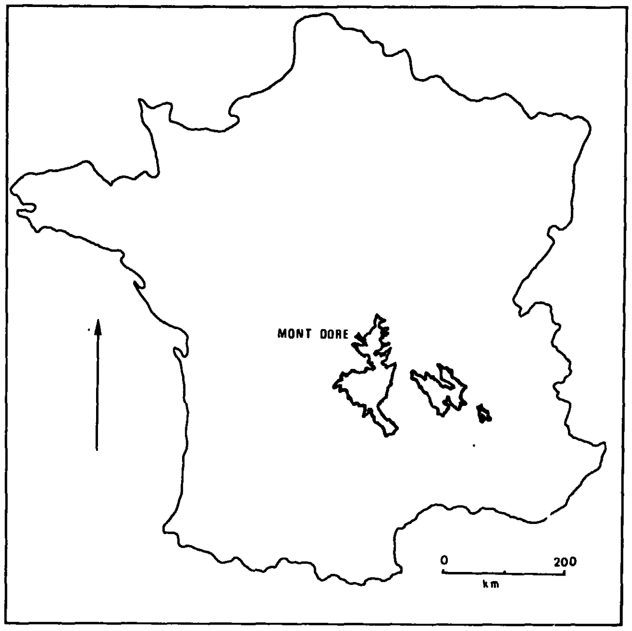

Fig. 1. Index map showing distribution of late Cenozoic volcanic rocks in central France.

GEOLOGY

Mont Dore volcano is located near the north edge of the volcanic field in central France (fig. 1). It is built upon a roughly north-trending horst of pre-Cenozoic schist, gneiss and granitic plutons. The volcano is highly modified by erosion, but it clearly thickens toward a central area where a minimum of 400 meters of section is exposed along the headwaters of the Dordogne River. In plan view, the volcano occupies a crudely circular area, about 20 km in diameter. Lavas of Mont Dore appear to interfinger with widespread basalt flows of the Cezallier Plateau to the south and are overlain to the east by Pleistocene and Holocene basalt of the Chaine des Puys, the youngest volcanic rocks in continental France (fig. 2).

Field relations and K-Ar ages suggest that Mont Dore grew since about 4 m.y. B.P. during two periods: (1) ~4 to 1.8 m.y. B.P. and (2) ~0.8 to

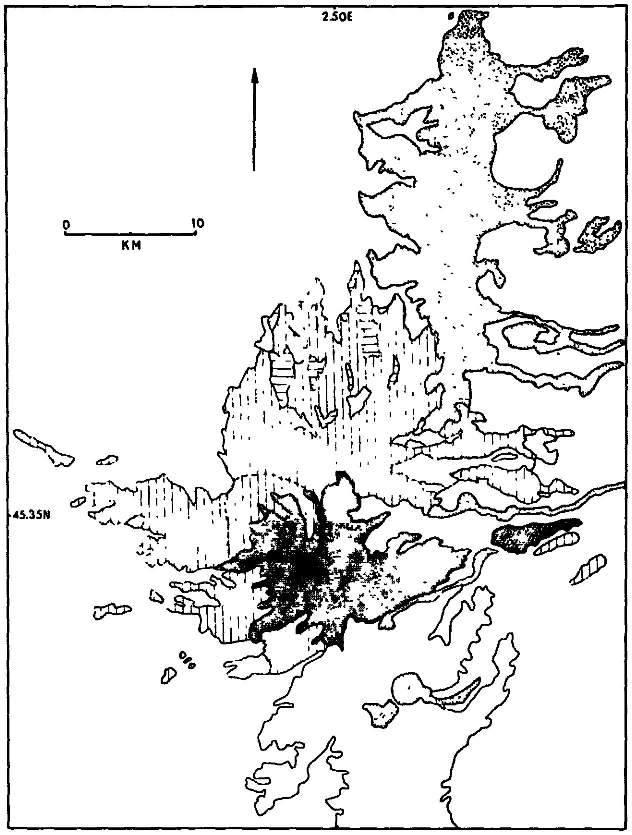

Fig. 2 Simplified geologic map of Mont Dore. Heavy broken line shows zone of steepest gradient in gravity field and is interpreted to outline caldera. Location of Puy Sancy is shown by •. Rocks of the Younger Period are shown by: -basalt, andesite, and dacite 0.8 to 0.25 m.y. Rocks of the Older Period are shown by: -basalt, tephrite, and phonolite 2.5 to 1.8 m.y.; -pumiceous, rhyolite ash flow 3.3 m.y.; and -pre-caldera basalt 4 to 3.4 m.y. Chaine des Puys volcanic shown by . Cezallier volcanics unpatterned.

0.25 m.y. B.P. Rocks of the older period are more varied lithologically than those of the younger, and are part of a caldera-forming cycle. Much of our field work to date has been aimed at delineating this caldera, within or beneath which a convective geothermal system is believed to exist. Post-caldera eruptions and erosion largely mask original caldera morphology and obscure the precise location of caldera walls.

The oldest lavas are basalt flows that were emplaced over a basement terrane of moderate to minor relief about 4.0 to 3.4 m.y. B.P. (fig. 2). These flows are overlain by a pumiceous, rhyolite ash flow that has yielded a K-Ar age of 3.3 m.y. Remnants of this ash flow are restricted to the north and east flanks of Mont Dore, but it is virtually unconsolidated and thus easily eroded where not protected by favorable topography or overlying resistant rocks. On the assumption that the deposit once blanketed all flanks of the volcano, we estimate its equivalent volume of magma to be several km^3, comparable to the probable volume of the caldera. We interpret the emplacement of the ash flow to be contemporaneous with caldera formation. Subsequent activity, in and near the caldera, includes emplacement of rhyolite domes (K-Ar ages of about 2.5 m.y.), and basalt and tephrite lava flows and phonolite intrusions (K-Ar ages of about 2.0 to 1.8 m.y.). Stratigraphic relations among these post-caldera rocks are generally obscure, but K-Ar ages suggest that emplacement of basalt flows was the last event in the older period of volcanism.

Rejuvenation of basaltic volcanism (K-Ar age of about 0.8 m.y.) initiated the younger period of activity. This period was characterized principally by the emplacement of several andesitic to dacitic domes and flows along the east margin of the caldera and by the growth of a stratovolcano along the south margin of the caldera. The present summit of this volcano (Puy Sancy) rises to 1885 meters elevation, the highest point in the Mont Dore area. Some flows on the flanks of Puy Sancy have yielded K-Ar ages of about 0.25 m.y. and other undated flows with little-eroded primary surfaces may be even younger.

GEOPHYSICS

Some geologic evidence helps define the position of the caldera: (1) The distribution of Paleozoic basement rocks indicates a downfaulted area in the central part of the volcanic pile. (2) A steeply dipping, east-facing escarpment in basement rocks near the west margin of the volcanic pile is interpreted to be part of a caldera fault scarp. (3) A concentration of post-caldera vents in the north, east, and south parts of the volcanic pile is interpreted to approximately trace part of the caldera boundary. A gravity map indicates a considerable section of low density material that is approximately coincident with the caldera as surmised from this geologic evidence.

The Bouguer gravity map is characterized by a negative anomaly of about 20 milligals (fig. 3). Though irregular in detail, the principal feature is a crudely circular low, whose zone of steepest gradient is interpreted to trace the shape of an underlying downfaulted block of basement rocks. Some apparent irregularities in the shape of this block might be removed by adjusting for the intracaldera distribution of rocks of differing densities. For example, whereas pyroclastic rocks are exposed at the surface over much of the caldera area, relatively dense lava flows crop out along the margins of the caldera, especially in the south and southeast sectors, in the vicinity of Puy Sancy; adjustment for these flows in the Bouguer correction would result in a less irregularly shaped gravity low.

Whatever the exact shape of the downfaulted block, gravity modelling studies suggest somewhat less than 1 km of relatively low density caldera fill. Geologic evidence suggests that such fill may include both syn-caldera pumice and overlying pyroclastic debris associated with post-caldera domes and flows.

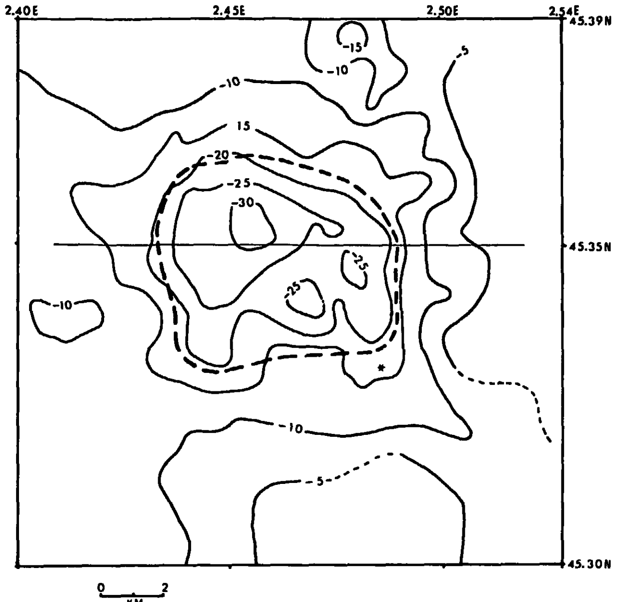

Fig. 3 Bouguer gravity map of Mont Dore area. Gravity reduction at density of 1.8 gm/cm^3. Heavy broken line traces zone of steepest gradient in gravity field and is interpreted to outline a caldera filled with low density rocks. See text for discussion. Light horizontal line is line of cross section for figure 4.

Geoelectric profiling and sounding indicate that the caldera fill is several hundreds of meters thick, consistent with the gravity-derived estimate, and is a good conductor. Measurements in adjacent Paleozoic basement terrane yield resistivities on the order of 300 to 1000 ohm meters, whereas those within pyroclastic rocks of the caldera yield values an order of magnitude less.

An aeromagnetic map of the region mainly highlights the position of post-caldera vents and associated lava flows. A well-developed, north-south magnetic lineation and a weaker east-northeast lineation reflect the principal directions of faulting. The north-south direction is roughly coincident with that of fault zones that bound the main horst upon which Mont Dore volcano lies. Similarly, cinder cones of the Chaine des Puys, which cuts the east flank of Mont Dore, are alined approximately north-south.

CONCLUSIONS

The geologic and geophysical studies indicate the presence of an approximately 6-km-wide caldera that is filled with ≤1 km of low density, probably pyroclastic, rocks (fig. 4). These rocks are good electrical conductors, consistent with the idea that they contain geothermal fluid and/or minerals deposited by such a fluid. A crustal magma reservoir that presumably erupted the pumiceous, rhyolite ash flow about 3.3 m.y. ago is probably too old to provide much thermal energy to the geothermal system. A much younger crustal magma reservoir, however, that is inferred to underlie Puy Sancy may still be a viable source of thermal energy.

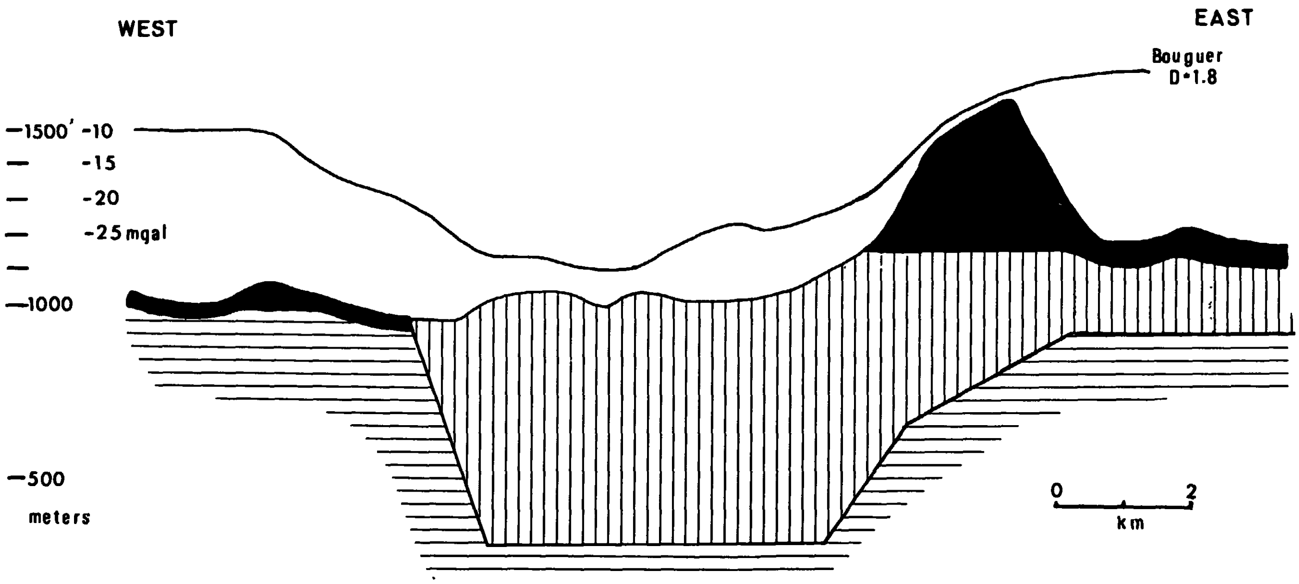

Fig. 4 Schematic east-west cross section across Mont Dore caldera (see figure 3). Adjustment in gravity modelling for thick section of relatively dense lavas near east end of section would extend the deep part of the caldera further east. See text for discussion. Pre-Cenozoic basement rocks are shown by ▤, pyroclastic rocks by ▥, and lava flows and domes by ■.