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GRANITIC ROCKS FROM THREE DEEP DRILL-HOLES, ILLINOIS

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ABSTRACT

A medium- and coarse-grained granite has been encountered in the lower 914 m of deep drill-holes in northwestern Illinois. The mineralogy and chemistry of both types of granite suggest they are anorogenic A-type granites after the definition of Loiselle and Wones (1979). The major oxide composition for both types is nearly identical. Trace element data (Rb, Y, Th) indicate the medium-grained granite crystallized from a more evolved melt than did the coarse-grained granite. Trace element data (Y, Th, Ba, Sr) for the coarse-grained granite show it to be slightly zoned from the bottom upward to the contact with the medium-grained granite at 731 m.

INTRODUCTION

Felsic igneous rocks appear to constitute an important segment of the late Precambrian geology of the north-central United States. In northern Wisconsin, epizonal granitic rocks have been described from outcrops by Anderson (1975), Anderson and Cullers (1978), and Van Schmus (1978). In southeastern Missouri, rocks similar in age and composition have been described by Kisvarsanyi (1972, 1981), Bickford and Mose (1975), Van Schmus et al. (1975a, 1975b), Pratt et al. (1980), Bickford et al. (1981), Cullers et al. (1981), and Thomas et al. (1984). However, in the intervening areas where they are obscured by a thick cover of Phanerozoic sedimentary rocks, study of these rocks has been carried out only on core recovered from scattered drill holes in Ohio (McCormick 1961), Iowa (Lidiak et al. 1966, 1983), Indiana (Kottlowski and Patton 1953), (Vitaliano, unpub. reports), and Illinois (Bradbury and Atherton 1965; Hoppe et al. 1983).

This covered central region has been described as part of a broad southwesternly trending arcuate province of late Precambrian felsic igneous rocks extending from the Great Lakes to the panhandle of Texas (Bickford and Mose 1975; Van Schmus and Bickford 1981; Thomas et al. 1984): from western Missouri east rocks yield ages of 1440–1480 Ma, and those west of western Missouri yield ages of 1350–1400 Ma (see Thomas et al. 1984). Van Schmus and Bickford (1981) suggested that these two terranes show evidence of crustal melting following accretion of calc-alkaline arcs during the period 1600–1800 Ma, the locus of melting shifting southwesterly with time.

The Commonwealth Edison Corporation drilled three holes (UPH-1, UPH-2, and UPH-3) in Stephenson County, northwestern Illinois in 1979–1980 in which granitic rocks were encountered starting at a depth of approximately 610 m below the collar. These holes afforded a number of investigators an opportunity to study physical and chemical properties of the Precambrian basement in an area of the midcontinent where little data had previously been obtained. Permission to study the cores was consequently obtained from the Commonwealth Edison Corporation by a special steering group of the Continental Scientific Drilling Committee.

C. J. Vitaliano and P. S. Dahl began a petrologic and petrochemical study of core UPH-3 employing thin section petrography, whole rock chemistry, and trace element analysis to determine: (1) if more than one granitic unit could be recognized, (2) if a differentiation trend could be detected in each unit, and (3) if a tectonic setting for the granitic rocks could be determined. G. R. McCormick began a mineral chemistry study on feldspars and micas on all three cores employing microprobe analyses, to determine the number of rock units, the presence or ab-

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sence of differentiation trend, and the tec-
tonic setting. The results of both research ef-
forts are so similar that they have been com-
bined in this present geologic note.

Unique petrogenetic interpretations of
trends, we have found, are not possible given
the limited suite of subsurface samples avail-
able for study. Rather, our purpose in this
paper is to contribute to an increasing data
base on buried mid-contontinental granitic
rocks, and to provide a useful reference for
future studies.

METHODS OF INVESTIGATION

Thin sections were prepared from 38 one-
inch-thick sections of NX core (UPH-1, three
samples; UPH-2, 12 samples; UPH-3, 23
samples). Each section was examined petro-
graphically, and the rock type of each sample
was determined by modal analysis (1,000
point counts per sample) using the IUGS
classification (Streckheisen 1976).

Whole-rock chemistry was obtained from
26 splits of pulp (3–5 cc each) from core
UPH-3 in the Silicate Analytical Laboratory
of the Department of Geology at Indiana
University. All samples were fluxed with lithium
borate, dissolved in acid, and analyzed with a
Jarrell-Ash Induction Coupled Plasma Spectrometer. Water was determined by the
USGS method described by Shapiro and
Brannock (1955). Analyses were made for 10
major oxides (SiO₂, TiO₂, Al₂O₃, Fe₂O₃,
MnO, MgO, CaO, Na₂O, K₂O, P₂O₅) and 11
trace elements (Ba, Cr, Cu, Mo, Ni, Pb, Sr,
Th, V, Y, Zn). Data for Rb were determined
by neutron activation. The precision, based
on counting statistics is ± 5%. GSP-1 was
used as a standard for all determinations.

Electron-microprobe data for the feldspars
and micas from 14 sections (UPH-1, one sample;
UPH-2, two samples; UPH-3, nine samples)
determined on an ARL-EMX-SM
electron microprobe using energy dispersion.
Concentrations of Na, Mg, Si, K, Ca, Ti, Mn,
and Fe were determined with the following
standards: Asbestos Microcline (K); Amelia
Albite (Na, Al, Si); Di85Jd15 glass (Mg);
Anorthite-50 glass (Ca); Al28 Ilmenite (Ti);
Hortonolite (Mn, Fe). The detection level for
each elements is near 0.2 wt % (1 sigma).
Background and peak counts were determined by
the procedures of Reed and Ware (1975), and
corrections were made with the factors of
Bence and Albee (1968).

PETROGRAPHY

The granitoid rock in the cores consists of
two textural varieties: (1) a fine- to medium-
grain phase in the uppermost 56 m and 1072
m level of core UPH-3 and the 1280 and 1372
m level of core UPH-2; and (2) a medium- to
crude-grained phase that makes up the re-
mainder of cores UPH-3 and UPH-2 and all
of core UPH-1. The major phase of the cores
is classified as granite sensu stricto; three
samples are quartz monzonite.

The fine- to medium-grained phase (hence-
forth referred to as fine-grained) is reddish-
brown to dark brown and composed of pink
K-feldspar (up to 5 mm in diameter) and gray
quartz anhedral (up to 1.5 mm in diameter) in
approximately equal proportions, along with
lesser quantities of plagioclase. All are em-
bedded in a dark reddish-brown lacy network
of iron oxide, biotite (chloritized in part),
muscovite, apatite and zircon.

The medium- to coarse-grained phase (hence-
forth referred to as coarse-grained) is red to
grayish-red, allotriomorphic, inequi-
granular, with seriate texture. Pink K-
feldspar, plagioclase, and gray quartz an-
hedra, all as much as 3.0 cm in diameter,
make up 84 to 95% of the rock. All are associ-
ated with a finer-grained (0.5 cm or less) frac-
tion of the above minerals mixed with musco-
vite, biotite, iron oxide, and accessory
apatite and zircon. Modal analyses of the
rock units do not yield any noticeable differ-
ence between the fine- or coarse-grained
units.

Note: Tabular data, including the modal
and microprobe analyses, and chemical com-
positions, normative values, and trace ele-
ment abundances for deep drill hole UPH-3
are available upon request from the National
Auxiliary Publications Service. Write ASIS/
NAPS, c/o Microfiche Publications, P.O.
Box 3513, Grand Central Station, New York,
NY 10163, for Document no. 04395 of 15
pages.

MINERALOGY

Quartz.—Constitutes 16 to 47% of the pri-
mary minerals. It occurs as globular, clear,
and strain-free bleb-like inclusions (0.05 mm)
in K-feldspar grains, as interstitial inclusion filled anhedral (up to 1.25 mm) between feldspar and ferromagnesian mineral grains, and in fractures associated with carbonate and other minerals introduced later. The interstitial quartz anhedral contain numerous needle-like inclusions of tourmaline. At the contact between the anhedral quartz and the biotite grains white mica, orthoclase (?), and iron oxide have formed as reaction products. In some thin sections the interstitial quartz has replaced K-feldspars; in others it has replaced biotite.

**K-feldspar.**—As microcline is the predominant feldspar. It comprises 13–49% of the rock and occurs as anhedral grains up to 3 cm in diameter, stained red with iron oxide and extensively converted to string perthite. Patches of white mica and clay are commonly surrounded by large areas that are devoid of any alteration. Fractures within the microcline are often filled with white mica and stained red with iron oxide, or are the sites for veinlets of chlorite, quartz, and fluorite. Microcline also hosts plagioclase anhedral and individual biotite grains along with the quartz anhedral mentioned above. The microcline microperthite, with the exception of that in samples UPH-2 (1455) and UPH-2 (905) yield orthoclase contents of 90–98 mole %. These analyses may be skewed and not reflect the whole chemistry of the microperthite, because clear zones between fine exsolution lamellae were generally chosen for analyses and are probably the areas of high potash content. Samples UPH-2 (1455) and UPH-2 (905) contained very fine exsolution lamellae on which a 10-micrometer beam spot was used. Analyses of these two samples yield 63–70 mole % orthoclase content and are considered more representative of the microcline microperthite chemistry.

**Plagioclase.**—Constitutes 17 to 49% of the primary mineral content and occurs as anhedral inclusions in K-feldspar, as stringers in microperthite, and as individual anhedral to subhedral grains up to 3.25 mm long. Generally, the plagioclase is altered in varying degrees of intensity. Plagioclase grains and plagioclase inclusions in K-feldspar are occasionally zoned and embayed and often consist of a core which is highly altered. This altered core is surrounded by a rim of unaltered plagioclase. Apatite and zircon are frequently included in the plagioclase. The plagioclase lamellae are occasionally bent or broken.

Plagioclase grains chosen for analyses are large euhedral phenocrysts or grains not associated with intergrain boundaries or borders. The composition of all samples except UPH-2 (902) and UPH-1 (631) ranges from 90–100 mole % albite; these latter two samples fall into the range for oligoclase.

The contact between the plagioclase and microcline is often the site for concentrations of muscovite, iron oxide, and quartz. The contact between plagioclase and biotite is the site for muscovite and iron oxide. Fluorite is often present as inclusions in plagioclase, but it may also occur in the interstices between plagioclase grains. Locally plagioclase is replaced by quartz.

**Muscovite.**—Constitutes 1.4 to 8.9% of the rock. There is no doubt that the majority of the muscovite or white mica is secondary; however, some sections also contain euhedral muscovite grains that were clearly terminated and about the same size as the biotite grains. If these muscovite grains are primary it would be possible to infer a minimum depth for the crystallization of the rock. Miller et al. (1981) have determined that primary muscovite is typically richer in Ti, Al, and Na and poorer in Mg and Si than secondary muscovite in the same sample. One analysis (UPH-3 (692)) is of a ragged grain of secondary muscovite; four other analyses were done of euhedral grains with clear terminations which could be primary muscovite. All five analyses are quite similar but cannot clearly be classified as primary or secondary according to Miller et al. (1981), although potassium and silicon values are closest to those values of Miller for secondary muscovite.

**Biotite.**—Constitutes 0.1 to 12.0% of the rock. The platy crystals are altered to green pleochroic chlorite, and the grain boundaries are always frayed due to replacement by one or another of the essential minerals. Oligoclase (?), white mica, and iron oxide are developed at the contact between biotite and microcline. Fluorite and titanite are present in these areas.

The biotite in core UPH-3 contains slightly more tetrahedral aluminum and more oc-
tetrahedral iron than the biotite from cores UPH-1 and UPH-2 (fig. 1). The biotite from all three cores contains nearly the same amount of titanium. The uppermost samples in UPH-3 (738) and (851) are distinctly poorer in magnesium than the lower samples, which could indicate a small extent of differentiation from the lower to upper part of the core.

Accessories.—Zircon, apatite, titanite, and fluorite occur as interstitial individual grains included in feldspar and micas. Some of the rocks contain as much as 2.0% fluorite, 1.9% zircon, and less than 1.0% apatite.

PETROCHEMISTRY

Major Elements.—The chemical composition of the UPH-3 granitic rocks fall into two groups, a low-silica (71.0 to 73.0%) and a high-silica group (73.0 to 75.4%). All rocks below 904 m except those at 1429 and 1127 m belong to the low-silica group. The two groupings notwithstanding, the silica content of the samples increases randomly from the bottom of the core up to and including the sample from 904 m; above 904 m the silica content remains relatively constant. The rocks are essentially corundum normative and marginally peraluminous; TiO₂, MgO, and CaO all increase with depth in the core. Na₂O and K₂O remain relatively constant, Na₂O at an average of 2.99 wt % and K₂O at an average of 5.63 wt %. K₂O exceeds 5.0 wt % in all except two samples: one from 1127 m (4.92 wt %) and the other from 1487 m (4.78 wt %). The K₂O/Na₂O molar ratio in all the samples exceed 1, and the 1514 m sample exceeds 2.

Some differentiation is indicated in a plot of TiO₂ versus MgO content (wt %) for samples from core UPH-3. Letters A to Z on the diagram correspond to the consecutive depths with A = 673 m and Z = 1604 m.

Trace Elements.—Elemental abundance values for barium, strontium, vanadium, zinc, yttrium and thorium in the fine-grained granite (above 731 m) exhibit little variation, whereas they exhibit progressive variation below that depth in the coarse-grained granite. Barium abundances are low in the shallow levels of the core and increase progressively with depth (fig. 3a); strontium, vanadium, and zinc similarly increase with depth. Yttrium abundances are highest in the shallow levels of the core and diminish with depth (fig. 3b); thorium abundances likewise diminish with depth.

DISCUSSION

Two distinct granites, a coarse-grained and a fine-grained, are observable in hand specimen and thin section from the cores. All whole rock major and trace element data for the fine-grained granite at the top of core UPH-3 above 731 m are clustered and distinctly different from those for the coarse-grained granite below that level.
The analyses of both fine- and coarse-grained granites are identical to analyses from rapikivi granites, granites from the Wolf River Batholith, and eight previous analyses of cores UPH-2 and UPH-3 (Lidiak and Denison 1983). All the granite analyses cluster around the peraluminous-metaluminous boundary of Shand (1951).

Plots of Rb vs. SiO₂ and Y vs. SiO₂ after the scheme of Pearce et al. (1984; fig. 2a,b) indicate all the granite samples are “within-plate granite.” The chemical analyses of all samples fit the description for A-type anorogenic granites (Loiselle and Wones 1979).

Analyses of biotite from all three cores (fig. 1) indicate that the biotite in all samples from core UPH-3 is slightly more iron-rich and slightly more aluminous than the biotite from cores UPH-1 and UPH-2. However, biotite in cores UPH-1 and UPH-2 is also richer in magnesium than the majority of samples from core UPH-3. Plagioclase from cores UPH-1 and UPH-2 is slightly more sodium-rich than that from core UPH-3.

High amounts of rubidium and yttrium and thorium (fig. 3) suggest that the fine-grained unit crystallized from a more evolved melt than did the coarse-grained granite below it. The coarse-grained granite in core UPH-3 below 731 m does seem to be slightly zoned from bottom upward to the contact with the fine-grained granite. Trace element data for Y, Th, Ba, and Sr (figs. 3a,b) show scatter but have definite trends. Yttrium and thorium increase from bottom to top, and barium and strontium decrease. The major elements do not indicate such a linear trend; however, a gross clustering can be observed. The deepest samples from core UPH-3 contain the highest TiO₂ and MgO, and the uppermost samples contain the least TiO₂ and MgO. The samples between, however, show considerable scatter and do not indicate a good trend.

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