AR\(^{39}\) Ar dating of plutonic rocks from Jersey, Channel Islands

R. S. D’lemos, R. D. Dallmeyer and R. A. Strachan


Two \(^{40}\)Ar\(^{39}\)Ar hornblende cooling ages have been determined from undeformed and unmetamorphosed plutonic rocks exposed on Jersey. Appinite from Le Nez (south-eastern plutonic complex) records a post-magmatic cooling age of 563 ± 1 Ma which defines a limit for deposition and subsequent regional deformation and metamorphism of host Brioverian volcanosedimentary sequences. A 472 ± 1 Ma post-magmatic cooling age was determined for hornblende from granodiorite at Sorel Point (north-eastern plutonic complex) and confirms previous isotopic evidence suggesting Ordovician magmatism on Jersey.

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INTRODUCTION

A variety of granite and associated basic to intermediate intrusions comprise three plutonic complexes exposed on the Channel Island of Jersey. These were emplaced into a deformed and metamorphosed volcanosedimentary sequence which has been correlated with Brioverian successions exposed in north-western France. Previously reported Rb-Sr whole-rock isochron ages from granites exposed on Jersey have been interpreted to suggest a broad continuum of plutonic activity from c. 550 to c. 425 Ma (Bland, 1984, 1985). K-Ar ages (Adams, 1976) for hornblende- and biotite-bearing rocks also suggest a protracted history. However, the reliability of the previously published data has sometimes been questioned. Possible non-closed system Rb-Sr behaviour resulting from magmatic and post-magmatic processes, is indicated by petrographic characteristics, and may mean that published ages for the granites are unreliable. The K-Ar ages, obtained by conventional methods, may have been affected by partial isotopic disturbance and/or excess argon, so that it is unclear how reliably any given age records initial emplacement. In an effort to better evaluate previously reported geochronologies, \(^{40}\)Ar\(^{39}\)Ar mineral analyses have been carried out. The advantage of this method is that progressive heating of a single sample evolves separate batches of Argon (Ar) which are dated independently. Assessment of the resulting age spectrum allows identification of contamination, partial isotopic rejuvenation and excess argon so that greater confidence may be placed on the interpretation of the data.

GEOLOGY OF JERSEY

The Cadomian orogen in the North Armorican Massif developed within a late Precambrian active continental margin setting (D’lemos et al., 1990; Dupret et al., 1990; Rabu et al., 1990). In northern parts of the massif early Cadomian magmatic arc-related plutons were deformed and metamorphosed along with host Palaeo-Proterozoic basement prior to c. 600 Ma (Dallmeyer et al., 1991a). Volcanic sequences and sedimentary rocks mainly derived from Cadomian arcs, were deposited into marginal and/or back-arc basins to form the Brioverian succession (Rabu et al., 1990; Dupret et al., 1990). Regional deformation and metamorphism of the Brioverian succession around the Baie de St Brieuc occurred c. 590-570 Ma (Guerrot and Peucat, 1990; Dallmeyer et al., 1991b). The age of Brioverian volcanism in some areas (e.g. Jersey) has been argued to be significantly younger (c. 530 Ma, Duff, 1978). Arc-related calcalkaline plutonism, which is post-tectonic with regards to local host rocks, is recorded in the Channel islands, at La Hague and in the Trégor region (Brown et al., 1990). The precise timing of this plutonism has been debated (e.g. Brown et al., 1990; Dallmeyer et al., 1992).

Recent \(^{40}\)Ar\(^{39}\)Ar mineral age data (Dallmeyer et al., 1992) suggest a c. 570 Ma age for post-tectonic magmatism on Guernsey and bring into question the geological significance of previously published Rb-Sr whole-rock isochron ages which span the Cambrian through to the Silurian (Adams, 1967, 1976; Bland, 1984, 1985; D’lemos, 1987a,b; Power et al., 1990).

GEOLOGICAL SETTING

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GEOLOGY OF JERSEY

Low-grade metasedimentary rocks of the Jersey Shale Formation and conformably overlying metavolcanic rocks of the Jersey Andesite and Jersey Rhyolite Formations are exposed along central portions of the Jersey coast (Figure 1) and in central parts of the island. They exhibit open north-south-trending folds and an associated cleavage which developed during anchizone to low greenschist facies metamorphism.

Figure 1: Geological map of Jersey (after Bland, 1984) showing sample localities.
A Rb-Sr whole-rock isochron age of 533 ± 16 Ma has been reported from the Jersey Andesite Formation (Duff, 1978), although the reliability of this age as dating eruption has been questioned (e.g. Bishop and Mournat, 1979). Plutonic complexes are exposed in south-eastern, south-western and north-western Jersey. They are composite and together comprise a range of compositions from olivine gabbro, through hornblende gabbro, diorite and granodiorite, to granite. Detailed descriptions of the complexes have been provided by Wells and Wooldridge (1931); Bland (1984) and Salmon (1987). Early workers attributed the complex nature of contact zones between basic and granite units and the origin of intermediate lithologies to a solid-state metasomatic alteration of basic rock during emplacement of granitic magmas (e.g. Wells and Wooldridge, 1931; Bishop and Key, 1983). Recent workers (Tomkins and Brown, 1984; Salmon, 1987, 1991) and argue that field, petrographic and geochemical features are primary and result from interaction between co-existing magmas. The plutonic complexes are generally undeformed and unmetamorphosed. Contacts are discordant to host rock structures. Contact metasomatic porphyroblasts overgrow the pre-existing cleavage in semi-pelitic host rocks. Together, these features demonstrate that the igneous complexes are younger than the host volcano-sedimentary sequences. In north-eastern Jersey, the post-orogenic Ro泽 Conglomerate Formation unconformably overlies the Jersey Andesite Formation.

PREVIOUS GEOCHRONOLOGY

The first Rb-Sr isotopic studies of Jersey plutons were undertaken by Adams (1967, 1976), Bland (1984) considered these whole-rock isochron ages unreliable because they were based on analyses of different components from each complex which could not be confidently assumed to have isotopically homogenized during formation. Bland (1984, 1985) reported results of Rb-Sr whole-rock analyses of six granitic units in the south-western and north-western complexes identified from geochemical and petrographic characteristics and considered to represent discrete isotopically homogenized magma pulses. The error of the age equation and the span of ages suggested a punctuated continuum of plutonic activity in Jersey from the Cambrian to Silurian. Although Bland’s (1985) data were analytically precise, the geological significance of the ages may be questioned on a number of grounds. Internal contacts between several units within individual complexes are gradational or irregular, suggesting penecontemporaneous magma mobility. The plutonic complexes are considered to be defined if the ages recorded by two or more contiguous magmatic processes, while in basic lithologies, hornblende is commonly intimately associated with clinopyroxene. Pure hornblende concentrates were prepared from two samples where field and petrographic evidence allow confident assignment of the hornblende to a primary igneous origin. Hornblende was extracted from appinite pegmatite at Le Nez and hornblende-hornblende granodiorite at Sore Point (Figure 1). 40Ar/39Ar analytical data are listed in Table 1 and are portrayed as incremental age and apparent K/Ca spectra in Figures 2 and 3.

APPINITE, LE NEZ: SOUTH-EASTERN PLUTONIC COMPLEX

Hornblende-plagioclase pegmatite was collected from an appinitic pod associated with layered gabbroic and dioritic rocks at Le Nez (Bishop and Key, 1983, 1984; Topley and Brown, 1984). Slightly zoned brown hornblende (up to 10 x 30 mm) occasionally exhibits a hollow-core.
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skeletal morphology attributed to rapid crystal growth within a posttectonic experiments on two hornblende concentrates from le Nez Appinite
J = 0.009160

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K/Ca spectra, with characteristics generally similar to those described for the Le Nez Appinite sample (Figure 3). The 890 to 1000°C increments comprise c. 94% of the gas evolved from the concentrate and are characterized by generally similar apparent K/Ca ratios. The nine increments define a 475.3 ± 1.5 Ma plateau age. Isotope correlation of the plateau data yields an inverse ordinate intercept of 382.2 ± 15.5 Ma and an age of 471.6 ± 1.4 Ma (MSWD = 1.02). This is considered geologically significant and is interpreted to date postmagmatic cooling through c. 500°C.

DISCUSSION AND CONCLUSIONS

The 563 ± 1 Ma 40Ar/39Ar hornblende age for the Le Nez sample is compatible with the c. 570 Ma 40Ar/39Ar post-magmatic mineral cooling ages reported for four components from the Northern Igneous Complex exposed on Guernsey (Dallmeyer et al., 1992), to post-magmatic cooling ages from the Fort Tourgis quartz diorite of Alderney, and the Moulins quartz diorite of La Hague (authors' unpublished data). Together these data suggest widespread c. 570-560 Ma post-tectonic cæl-alkaline magmatism in the northern part of the Armorican Massif.

Although not in direct contact, field relationships from the igneous complexes as a whole strongly indicate a younger age for the Le Nez appinite than the deformation and regional low-grade metamorphism of the Jurassic shale and volcanic sequences. The c. 560 Ma age for the south-eastern plutonic complex thus provides a limit for the deposition and subsequent regional deformation and metamorphism of the Brioverian rocks of Jersey and is consistent with 40Ar/39Ar cooling ages recorded for metamorphosed Brioverian rocks exposed around the Baie de St Bréuc (Dallmeyer et al., 1991b). The new age data implies that the 533 ± 16 Ma Rb-Sr whole-rock isochron age reported by Duff (1978) for the Jersey Andesite Formation does not record eruption and thus removes the isotopic basis for correlation with supposed Cambrian hyperbyssal and extrusive volcanic units of the Trégor region (Auvray, 1979; Dupret et al., 1990).

The c. 470 Ma age for the granodiorite at Sorel Point is significantly younger than all other mineral ages determined by 40Ar/39Ar methods for Cadomian intrusions in the Channel Islands-La Hague region. It is similar to the K-Ar ages provided by Adams (1976) and, within error, is similar to the Rb-Sr whole-rock isochron age of 465 ± 10 Ma reported by Bland (1984; 1985) for the volumetrically dominant Porphyritic Granite member of the northwestern plutonic complex. The c. 470 Ma age is, however, significantly older than the age quoted for the microgranite exposed adjacent to the basic to intermediate rocks at Sorel Point. The well-defined plateau pattern of the 40Ar/39Ar release spectra demonstrates that the c. 470 Ma age is not an artefact of partial resetting, but records the age of cooling through c. 500°C. Complete rejuvenation of the amphibole during cooling through c. 500°C.

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REFERENCES


