

ISOTOPIC DATING OF THE POST-ALPINE NEOGENE VOLCANISM IN THE BETIC CORDILLERAS, SOUTHERN SPAIN¹

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ABSTRACT

Nobel, F. A., P. A. M. Andriessen, E. H. Hebeda, H. N. A. Priem & H. E. Rondeel 1981 Isotopic dating of the post-Alpine Neogene volcanism in the Betic Cordilleras, southern Spain – Geol. Mijnbouw 60: 209-214.

The post-Alpine lamproitic volcanism in the Prebetic of the External Zone of the Betic Cordilleras of southern Spain is dated at 7.6-7.2 Ma by the K-Ar data from two richterites, two sanidines, a phlogopite and a whole-rock, and the fission-track analysis of an apatite. Biotite from a lava of the rhyolitic-dacitic suite in the post-orogenic Vera basin of the Internal Zone produces the same age. Phlogopite from a lamproitic (veritic) subvolcanic body in the Vera basin yields an age of about 8.6 Ma; as lavas belonging to the veritic suite reportedly overlie Late Messinian sediments, pointing to an age of less than about 5 Ma, this type of volcanism in the Vera basin must have been active over several million years.

INTRODUCTION

Post-Alpine volcanism occurred at several places in the easternmost part of the Betic Cordilleras, the Alpine orogenic belt along the Mediterranean coast of southern Spain. Manifestations of the Neogene volcanic activity are found over a wide area in a number of small occurrences, both in the Internal Zone (the nappe complex) and in the so-called Prebetic of the External Zone (Fig. 1). In the External Zone the volcanism post-dates the thrusting of the Subbetic onto the Prebetic, to which movements an Helvetian-Tortonian age has been assigned (HOEDEMAKER, 1974; JEREZ-MIR, 1973; AZEMA, 1977). The volcanism in the Internal Zone is subsequent to the Alpine thrusting and main phases of folding.

On the basis of petrological and chemical characteristics three groups can be distinguished among the volcanic rocks (Fig. 1), as follows:

(1) The calc-alkaline volcanism extending from Cartagena to Almería with compositions ranging from andesitic to rhyolitic. K-Ar whole-rock age measurements on 18 samples from this suite collected all over the zone yielded ages between about 15.7 and 8.0 Ma⁴ (BELLON, 1976; BELLON & BROUSSE, 1977). In the northern Cabo de Gata region this volcanism becomes progressively more basic with decreasing age (FÚSTER, 1956).

(2) The (per)potassic lamproites characterized by high K and Mg and low Al, Fe and Ca contents. FÚSTER ET AL. (1967) distinguished four types of lamproites on the basis of normative mineralogy: (a) jumillites, undersaturated rocks containing both normative olivine and leucite, (b) cancalites, undersaturated rocks containing normative olivine, (c) fortunites, saturated rocks containing less than five percent normative olivine or quartz, and (d) verites, saturated rocks containing more than five percent normative quartz. For a verite from the Vera basin and a fortunite from Fortuna K-Ar whole-rock ages have been reported of 10.9±1 Ma and 6.1±0.4 Ma⁴, respectively (BELLON, 1976; BELLON & BROUSSE, 1977). A lamproitic lava near Barqueiros yielded a K-Ar whole-rock age of about 7.0 Ma⁴ (VAN COUVERING ET AL., 1976).

(3) The olivine basalts north and northwest of Cartagena; for

¹ Manuscript received: 1980-11-24.

Revised manuscript received and accepted: 1981-01-23.

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⁴ Ages recalculated with the IUGS recommended constants used in this study.

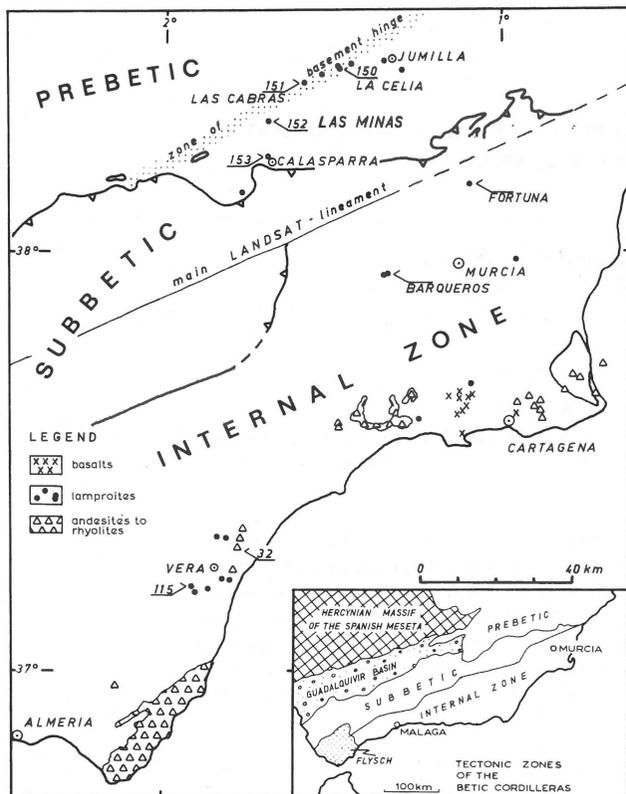


Fig. 1
Map showing the sample locations and the distribution of the three groups of post-Alpine volcanic rocks in southern Spain in relation to the main tectonic features and subdivisions.

which a Plio-Quaternary age has been determined (2.6-2.8 Ma⁴; BELLON, 1976; BELLON & BROUSSE, 1977). These rocks are not included in this study.

K-Ar measurements were made on five separated minerals and a whole-rock of four lamproitic rocks from the Jumilla-Calasparra area in the Prebetic zone, some 60 km NW of Murcia. Also, a fission-track analysis was performed on apatite from one of the samples. Moreover, K-Ar analyses are reported of two (sub)volcanic rocks in the Vera basin, the Neogene basin along the Mediterranean coast around Vera within the Internal zone, one biotite from a rhyolite and one phlogopite from a verite. The sampling sites are shown in figure 1.

VOLCANIC ROCKS FROM THE JUMILLA-CALASPARRA AREA

Four samples were investigated, coming from the eruptive centres of La Celia, Las Cabras, Las Minas and Calasparra (Fig. 1). The eruptive centres near Las Cabras and La Celia are located at the basement hinge that for a long time through geologic history has been manifest along a NE-SW line through Jumilla (Fig. 1). This hinge is reflected in the facies

distribution from the Late Jurassic onwards (AZEMA, 1977) and is also defined by the occurrence of domes of Triassic gypsum and salt; a few of such domes have been intruded by lamproites. Moreover, it is thought that its presence is the principal cause of the tectono-stratigraphic subdivision of the Prebetic zone into an internal and an external part (e.g. RODRIGUEZ-ESTRELLA, 1977). The hinge, presumably a major basement fault zone, is structurally defined by a zone of intense Tertiary deformation with a vergence to the south; this contrasts with the predominantly opposite vergence elsewhere in the Prebetic zone.

There is no clear relation between the Las Minas and Calasparra eruptive centres and basement structures. Both centres are roughly aligned with the small outcrop of lamproitic rocks reported by HERMES (1978) at the Subbetic from SW of Calasparra (Fig. 1). A NNE-trending fault zone along this line has been suggested by JEREZ-MIR (1973), but no arguments other than the alignment of the three eruptive centres does support the existence of such a fault zone.

The rocks occur in breccia-mantled pipes and dikes and only rarely as subaerial extrusions. The mineralogy is rather conspicuous: diopside, enstatite, forsterite, Ti-phlogopite, K-richterite, sanidine, apatite and, in the undersaturated varieties, leucite. A summary of the petrography and chemistry has been given by FÚSTER ET AL. (1967) and BORLEY (1967). Chemical analyses of the sanidine and diopside were made by FERMOSE (1967-a, b). The richterite has been analysed by HERNÁNDEZ PACHECO (1965). Moreover, Rb/Sr and ⁸⁷Sr/⁸⁶Sr data have been reported by POWELL & BELL (1970).

All four investigated samples come from more or less circular pipes with diameters of about 400 to 1000 m. The samples from La Celia (ALM 150) and Las Cabras (ALM 151), a jumillite and a cancalite, respectively, are both porphyritic rocks with phenocrysts of richterite and sanidine in a groundmass of olivine, clinopyroxene, phlogopite, apatite and, at La Celia, leucite. Richterite and sanidine are intergrown with subophitic texture, containing numerous inclusions of all other constituents. The fortunite sample from Las Minas (ALM 152) is composed of phenocrysts of phlogopite embedded in a fine-grained groundmass of sanidine and glass. Small crystals of clinopyroxene and apatite are enclosed within the phlogopite. The cancalite sample from Calasparra (ALM 153) is a porphyritic rock containing phenocrysts of olivine and phlogopite within a fine-grained groundmass largely composed of sanidine. Flow structures result from the parallelism of the sanidine crystals, which display poikilitic intergrowths with euhedral phlogopite, clinopyroxene and apatite, and anhedral richterite.

Biostratigraphy

Figure 2 shows the stratigraphic position of the volcanic rocks in the Jumilla-Calasparra area, based on FÚSTER ET AL. (1967), JEREZ-MIR (1973) and observations by two of the present authors (F.A.N. and H.E.R.). The general stratigraphic

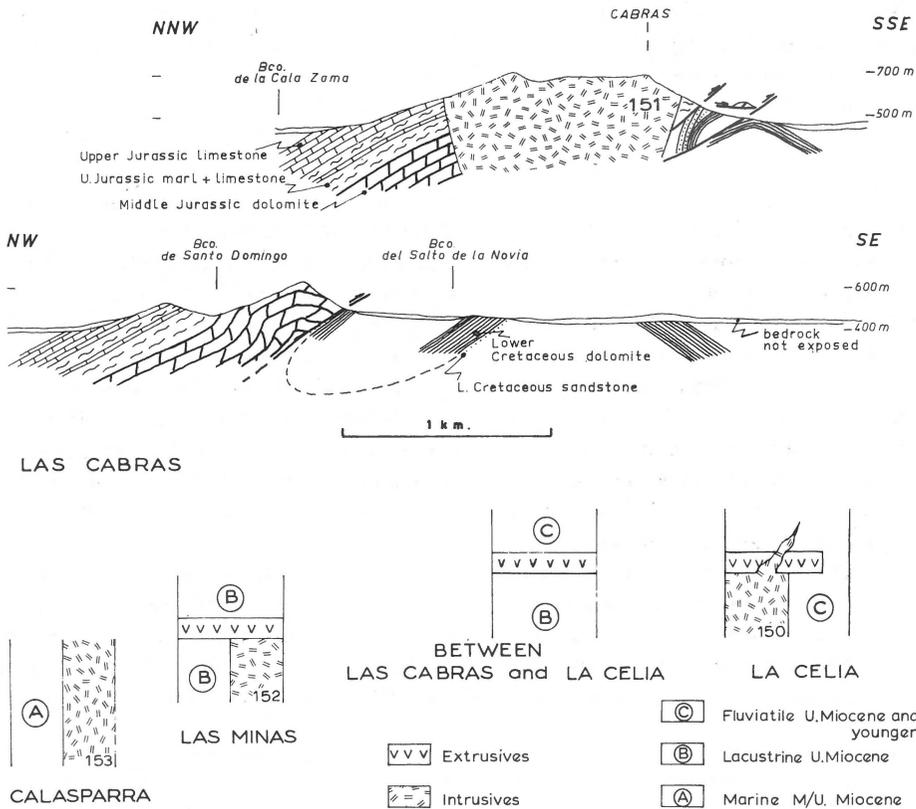


Fig. 2
Schematic representation of the stratigraphic and structural setting of the investigated lamproitic eruptive centers in the Prebetic.

relations are according to JEREZ-MIR (1973), CALVO-SORANDO (1978), CALVO ET AL. (1978) and personal observations (F.A.N. and H.E.R.).

Near Calasparra, a pipe transects marly sediments belonging to a marine sequence (A) which occurs over the entire Prebetic area now under discussion. At many places these sediments are strongly arenaceous. They often have a bioclastic character. The fauna indicates a Miocene age, Langhian up into Tortonian (IGME, 1974; JEREZ-MIR, 1973).

Sequence A is covered by and laterally interfingers with a lacustrine facies (sequence B) of predominantly calcareous and marly sediments (JEREZ-MIR, 1973; IGME, 1974). In the northern part of the area the higher levels of this sequence have been dated on the basis of their fossil contents as Late Turolian by CALVO ET AL. (1978). The pipes near Las Minas have intruded sequence B, the associated lavas are interbedded.

At several places the Miocene deposits have been strongly tectonized. For the pipe of Las Cabras the relative age is estimated from the relationships with the structural elements: younger than the southward thrusting which affected sequence A elsewhere in the area.

The marine and lacustrine Miocene sediments have locally been strongly disturbed prior to the deposition of a sequence of fluvatile sediments (C). They show many internal uncon-

formities and the contact with the predominantly flat-lying, reddish sequence C also seems of unconformable nature. Fossils have never been reported, but it is customarily assumed that sequence C is of Pliocene-Quaternary age. The fluvatile sediments overlie a lamproitic flow between Las Cabras and La Celia, but near La Celia the lavas are intercalated and the intrusions transect sequence C.

(SUB)VOLCANIC ROCKS FROM THE VERA BASIN

Two samples were investigated, one of each of the two types of (sub)volcanic rocks distinguished in the Vera basin (Fig. 1), the rhyolitic-dacitic suite and the verites (FÜSTER, 1967). From the rhyolitic-dacitic suite a biotite was analysed (ALM 32) and from the verites a phlogopite (ALM 115). The rhyolitic-dacitic extrusive masses are located along a NNE-trending line in the eastern part of the basin (VÖLK, 1967). Veritic lavas occur at several places throughout the basin and form also the intrusive mass of Cabezo Maria.

The rhyolitic lava sample comes from the Estrecho de Alifraga. It is a porphyric rock consisting of phenocrystic biotite and minor sanidine in an extremely fine-grained groundmass in which quartz, sanidine and glass can be discerned. The verite sample comes from the subvolcanic body

forming the Cabezo Maria. The rock contains many small phenocrysts of phlogopite and smaller ones of olivine in a glassy groundmass in which minute phlogopite flakes and diopside microlites are visible.

Biostratigraphy

The stratigraphy of the Vera basin, including the biostratigraphic position of the (sub)volcanic rocks, has been studied by VÖLK (1967). Veritic lavas rest on the upper members of the Turre Formation, to which a late Messinian age is assigned on the basis of planktonic foraminifera by GEERLINGS ET AL. (1980). MONTENAT ET AL. (1976) attribute the nannoplankton from these levels to zone NN 12. Sediments overlying the veritic lavas (the Cuevas Formation) contain a pelagic fauna indicative of an Early/Middle Pliocene age (MONTENAT ET AL., 1976; GEERLINGS ET AL., 1980). With regard to the rhyolitic-dacitic extrusions, it can be ascertained (VÖLK, 1967) that they occurred before the deposition of sediments (the Espiritu Santo Formation) containing planktonic foraminifera of Late Pliocene age. According to Th.B. Roep (pers. comm.) it has been established at one place that the rhyolitic-

dacitic lavas are nonconformably overlain by sediments of Early Pliocene age (the Cuevas Formation).

EXPERIMENTAL PROCEDURES

The minerals were separated from the sieve fractions $-250+125\ \mu\text{m}$ by means of a laboratory overflow centrifuge employing a set of stabilized heavy liquids (IJLST, 1973-a, b) and a modified Frantz isodynamic magnetic separator (VER-SCHURE & IJLST, 1969). A purity of over 99.9% was obtained. For sample ALM 153 the $-250+125\ \mu\text{m}$ sieve fraction of the pulverized rock was used for the K-Ar analysis.

The K contents were determined by flame photometry with a lithium internal standard and caesium-aluminium nitrate buffer. Argon was extracted in a bakeable glass vacuum apparatus and determined by isotope dilution techniques on a Varian GD-150 mass-spectrometer.

The population technique was used for the fission-track dating of apatite ALM 150. Etching was performed with 5% HNO_3 during 45 seconds at 21 °C. The thermal neutron flux was determined by counting the National Bureau of Standards glass SRM 963, using the Cu neutron dose calibration.

Table I
K-Ar data and calculated ages.

Sample Nr	Material	K (% Wt)	radiogenic ^{40}Ar (ppm $\times 10^3$)	atmospheric ^{40}Ar (% total ^{40}Ar)	calculated age (Ma)*
<i>Prebetic zone</i>					
ALM 150	sanidine	10.53	5.12	15	} 7.2±0.3
La Celia		10.52	5.33	13	
			5.35	15	
ALM 150	richterite	6.02	3.21	60	} 7.6±0.2
La Celia		6.02	3.19	66	
ALM 151	sanidine	12.73	6.50	24	} 7.3±0.2
Las Cabras		12.79	6.46	17	
ALM 151	richterite	4.20	2.15	47	} 7.6±0.3
Las Cabras		4.17	2.27	53	
ALM 152	phlogopite	8.42	4.01	54	} 7.2±0.4
Las Minas		8.42	4.23	53	
			4.31	58	
ALM 153	whole-rock	7.96	3.99	58	} 7.2±0.2
Calasparra		7.97	4.02	58	
<i>Vera basin</i>					
ALM 32	biotite	7.34	3.98	60	} 7.6±0.3
		7.32	3.79	59	
ALM 115	phlogopite	8.12	4.85	76	} 8.6±0.3
		8.13	4.80	78	

* The errors in the ages are the sum of the estimated contributions of the known sources of possible systematic error and the precision (2σ) of the total analytical procedures. The ages are based upon the IUGS recommended set of constants: $\lambda_e(^{40}\text{K}) = 0.581 \cdot 10^{-10} \text{a}^{-1}$, $\lambda_\beta(^{40}\text{K}) = 4.962 \cdot 10^{-10} \text{a}^{-1}$ and abundance $^{40}\text{K} = 0.01167$ atom percent total K.

RESULTS AND DISCUSSION

The analytical data and calculated ages are listed in tables I and II. All ages from the volcanic centres in the Jumilla-Casparra area lie between 7.2 and 7.6 Ma, the fission-track apatite age being concordant with the K-Ar ages. Taking into account the limits of error, it is not possible to decide whether the differences in measured ages (7.6 Ma for the richterites versus 7.2-7.3 Ma for all other systems) are significant. Anyhow, an age of 7.6-7.2 Ma can be assigned to the volcanic activity in this area.

The biotite of the rhyolite from the Vera basin (ALM 32) produces a K-Ar age of 7.6 ± 0.2 Ma, which points to an approximate contemporaneity of the outpouring of these rhyolitic-dacitic lavas and the potassium-rich volcanism in the Prebetic zone. This age is somewhat younger than the lower age limit of the calc-alkaline volcanism in southern Spain according to BELLON (1976) and BELLON & BROUSSE (1977). A higher age of 8.6 ± 0.3 Ma is displayed by the phlogopite from the veritic subvolcanic rock (ALM 115), indicating that this intrusion is about 10^6 year older than the rhyolitic-dacitic volcanism. As veritic lavas in the Vera basin rest on late Messinian sediments and a K-Ar whole-rock age of 10.9 ± 1 Ma has been reported by BELLON (1976) and BELLON & BROUSSE (1977), the veritic volcanism appears to have been active over several million years.

In the Neogene time-scale (Table III), the Pliocene (Zanclian)/Messinian, Messinian/Tortonian and Tortonian/Serravalian stage boundaries are taken at about 5 Ma, 8 Ma and 12 Ma, respectively (Vass, 1975, in VASS & BAGDASARIAN, 1978), but the Messinian/Tortonian boundary is also dated at 6.5 Ma (Ryan et al., 1974, in VASS & BAGDASARIAN, 1978). The age data reported in this paper thus indicate that the potassium-rich volcanism in the Prebetic zone took place in the late Tortonian and/or early Messinian. This implies that the allegedly Pliocene-Quaternary fluvial deposits of Las Cabras and La Celia (C in Fig. 2) are in fact much older, pre-early Messinian, as they are transected near La Celia by the volcanic pipes.

Table II
Fission-track data and calculated age apatite ALM 150.

Q_{ss} , tracks/cm ²	$1.16 \cdot 10^4$
number of tracks counted:	134 (236 grains)
Q_i , tracks/cm ²	$1.06 \cdot 10^5$
number of tracks counted:	431 (83 grains)
Φ neutrons/cm ²	$1.31 \cdot 10^{15}$
number of tracks counted:	2714
calculated age:	7.2 ± 1.4 Ma*

* Constants used: $\lambda_F = 8.57 \cdot 10^{-17} \text{ a}^{-1}$ (Thiel & Herr, 1976); $^{235}\text{U}/^{238}\text{U} = 7.252 \cdot 10^{-3}$; $\sigma_f = 580 \cdot 10^{-24} \text{ cm}^2$.

ACKNOWLEDGEMENTS

The authors are much indebted to N. A. I. M. Boelrijk, E. A. Th. Verdurmen and R. H. Verschure, all of the Z.W.O. Laboratory of Isotope Geology, Amsterdam, for valuable discussions and indispensable help in the laboratory, and to Th. B. Roep, Dept. of Geology, University of Amsterdam, for providing some field data. For the irradiation of the apatite use was made of the facilities of E.C.N., Petten. The investigation was carried out with the consent of the Comisión Nacional de Geología de España. This work forms part of the research programme of the 'Stichting voor Isotopen-Geologisch Onderzoek', supported by the Netherlands Organization for the Advancement of Pure Research (Z.W.O.).

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Table III
Ages obtained from the post-Alpine volcanic rocks in southern Spain in relation to the world Neogene time-scales*

(1)	(2)	Prebetic lamproites	Verite	Rhyolite from Vera
Pliocene	Zanclian			
— 5.05—	— 5.2—			
Messinian	Messinian			
— 7.95—	— 6.5—	7.2-7.6		7.6
Tortonian	Tortonian		8.6	
—12.19—	—12.0—			
Serravalian				

* (1) Geochronological scale, based on isotopic ages (Vass, 1975, in Vass & Bagdasarjan, 1978). (2) Palaeomagnetic assignment of the Neogene stage boundaries (Ryan et al., 1974, in Vass & Bagdasarjan, 1978).

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