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Early Permian age of granite pebbles from an Eocene or Oligocene conglomerate of the Internal Rif belt (Alboran domain, Morocco): hypothesis on their origin

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Abstract – Granite pebbles from an Eocene or Oligocene conglomerate lying on a Ghomaride nappe of the Internal Zones of the Rif belt (Alboran domain, Morocco) have been dated by U/Pb on zircon at 281 Ma. No granite pluton being known in the Rif belt nor in the neighbouring Betic Cordillera, the origin of these calc-alkaline Kungurian (end of the Early Permian) granites is discussed. A provenance from a nearby unit presently drowned in the Alboran sea is likely. Comparisons with other circum-Mediterranean domains show that this late plutonism characterizes an original domain in the Variscan orogen.

Keywords: granite / Rif belt / Alboran domain / Variscan / U/Pb zircon / Kungurian

Résumé – Âge Permien inférieur de galets de granite provenant d'un conglomérat éocène ou oligocène du Rif interne (Domaine d'Alboran, Maroc): hypothèses sur leur origine. Des galets de granites provenant d'un conglomérat éocène ou oligocène reposant sur une des nappes ghomarides des Zones Internes de la Chaîne rifaine (Domaine d'Alboran, Maroc) sont datés par U/Pb sur zircons à 281 Ma. Aucun pluton granitique n'étant connu dans le Rif ni dans les Cordillères bétiques voisines, cet âge Kungurien (fin du Permien inférieur) représente une donnée importante pour discuter l'origine de ces granites calco-alkalins. Une provenance à partir d'une unité proche aujourd'hui submergée en mer d'Alboran paraît la plus probable. Par comparaison avec les autres domaines circum-méditerranéens, ce plutonisme très tardif par rapport aux âges du Carbonifère supérieur et du Permien basal caractérisant une grande partie de Chaîne hercynienne, fait de l'ensemble bético-rifain un domaine original au sein de cet orogène.

Mots clés : granite / chaîne rifaine / domaine d'Alboran / hercynien / U/Pb zircon / Kungurian

1 Introduction

The Rif belt (northern Morocco) (Chalouan *et al.*, 2008 and references herein) belongs to the Western Mediterranean alpine chain, with the Betics in southern Spain, Kabylia in northern Algeria, Peloritian Mountains in Sicily and Calabria in southern Italy. These now scattered belts are generally considered as remnants of the AlKaPeCa terrane (Bouillin *et al.*, 1986) dismembered during the Miocene. The internal zones of the Rifian and Betic belts form the Alboran domain (originally the Alboran microplate of Andrieux *et al.*, 1971) affected by both Variscan and Alpine deformations. This domain would have been initially located along the eastern

coast of the Iberian plate, to the south of the Sardinia-Corsica block (*e.g.*, Rosenbaum *et al.*, 2002). Contrary to other ranges around the Mediterranean sea, the Betic-Rif belt is characterized by the lack of granitic pluton. However, a first discovery of granitic pebbles in a Tertiary (post-Upper Ypresian) conglomerate belonging to the cover of the internal Rif was reported by Olivier *et al.* (1979). Later, other discoveries of granitic pebbles in Upper Oligocene-Lower Miocene conglomerates from various units of the Betic-Rif belt were mentioned by Martín-Algarra *et al.* (2000), Puglisi *et al.* (2001), Zaghloul *et al.* (2003) and Gigliuto *et al.* (2004). These authors proposed various origins for these granites either on the basis of paleogeographic considerations or on the basis of geochemical analyses. None of them have used geochronological arguments, these granites being of unknown or poorly defined ages. In this paper, we present a well-defined date of

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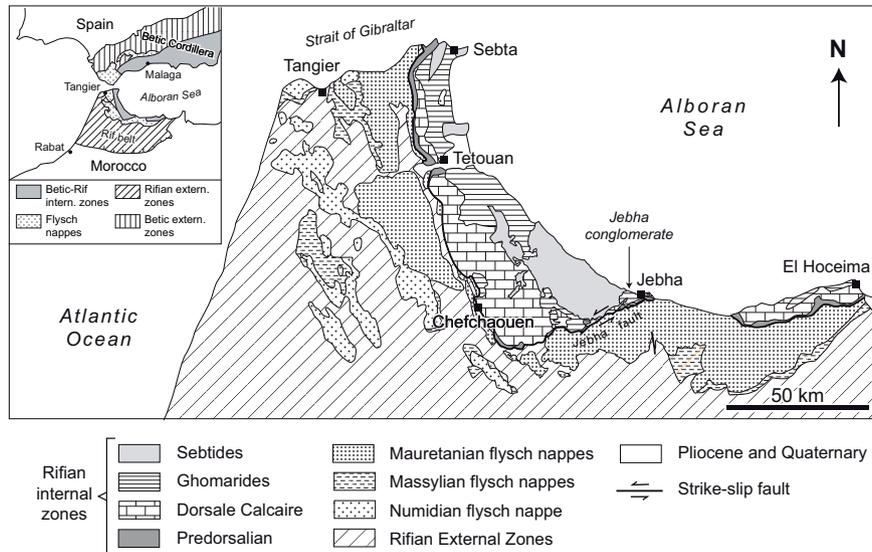


Fig. 1. Location of the Jebha conglomerate in the Internal Zones of the Rif chain.

the granitic pebbles mentioned by [Olivier et al. \(1979\)](#). On the basis of this new date and of geochemical analyses, we propose a possible origin for these granites.

2 Geological setting

The main units of the internal Rif ([Fig. 1](#)), and their equivalent in the western Betic Cordillera, are:

- the Sebtides (Rif) – Alpujarrides (Betics) constituted by the huge slices of mantellic peridotites of Beni Bousera and Ronda, kinzigites, HP paragneisses, rare orthogneisses and micaschists, Paleozoic or older in age, and a Permian and Triassic cover of metapelites and metacarbonates;
- the Ghomarides (Rif) – Malaguides (Betics) constituted by unmetamorphosed or slightly metamorphosed Paleozoic formations, with a thin Mesozoic and Paleogene up to Lowermost Miocene sedimentary cover;
- the Dorsale Calcaire formed by generally unmetamorphosed calcareous series of the Lower Mesozoic and Eocene to Upper Oligocene marly and conglomeratic formations;
- the Predorsalian units representing a transition zone between the Dorsale and the Flyschs domains.

The Flyschs nappes formed by Lower Cretaceous to Lower Miocene turbiditic series are located between the internal and external zones. The Rifian external zones correspond to the African foreland, and the Betic external zones correspond to the Iberian foreland.

The conglomerate containing the granitic pebbles studied in the present paper lies stratigraphically, but in a reverse position, on Paleozoic strata of a Ghomaride unit (Akaïli unit), 5 km to the WNW of Jebha (x: 4° 43' 11" W, y: 35° 13' 00" N) on the Mediterranean coast of central Rif ([Fig. 1](#)). This unit is here represented by Silurian schistosed pelites, Silurian to

Devonian paleovolcanic rocks, Devonian limestones and Triassic red sandstones and conglomerates ([Fig. 2](#)).

The Jebha conglomerate is represented by two neighbouring decametre-scale outcrops, displaying a dominantly red color, probably due to the Triassic red sandstones upon which this conglomerate was deposited. The matrix is composed of sandstones and pelites. The reworked elements are generally well rounded but poorly sorted, centimetre-scale up to one metre in diameter for some sandstones, up to fifty centimetres for the granites. These clasts (*i.e.*, pebbles, cobbles and boulders in the [Pettijohn \(1975\)](#) classification) are composed of very various sedimentary, metamorphic, volcanic and plutonic rock types.

The sedimentary rocks are mainly sandstones and limestones. The most characteristic limestones are represented by Liassic dismicrites and by foraminifer-bearing limestones which were dated by *Alveolina gr. oblonga*, *A. gr. minutula*, *A. cf. rutimeyeri*, *A. gr. tenuis* or *stipes* and *Nummulites granifer*, *N. campesinus*, *N. manfredi*, *N. leupoldi* as Cuisian (Upper Ypresian) ([Olivier, 1990](#), p. 134) giving then a maximum age to the conglomerate. The metamorphic rocks are quartzites and micaschists without characteristic minerals. The volcanic rocks are more or less weathered basalts of unknown age and origin. The plutonic rocks, *i.e.* various granite types, are described in the following section.

3 Petrographic description and geochemical analyses of the granite pebbles

Various facies of non-weathered two-mica granites were observed, with millimetre- up to a few centimetre-sized grains, *i.e.* fine-grain leucogranite, microgranite and more or less porphyritic granite ([Fig. 3A–D](#)). The paragenesis of most of these facies are similar with quartz, orthoclase and microcline, plagioclase, biotite and muscovite (primary and secondary). Some

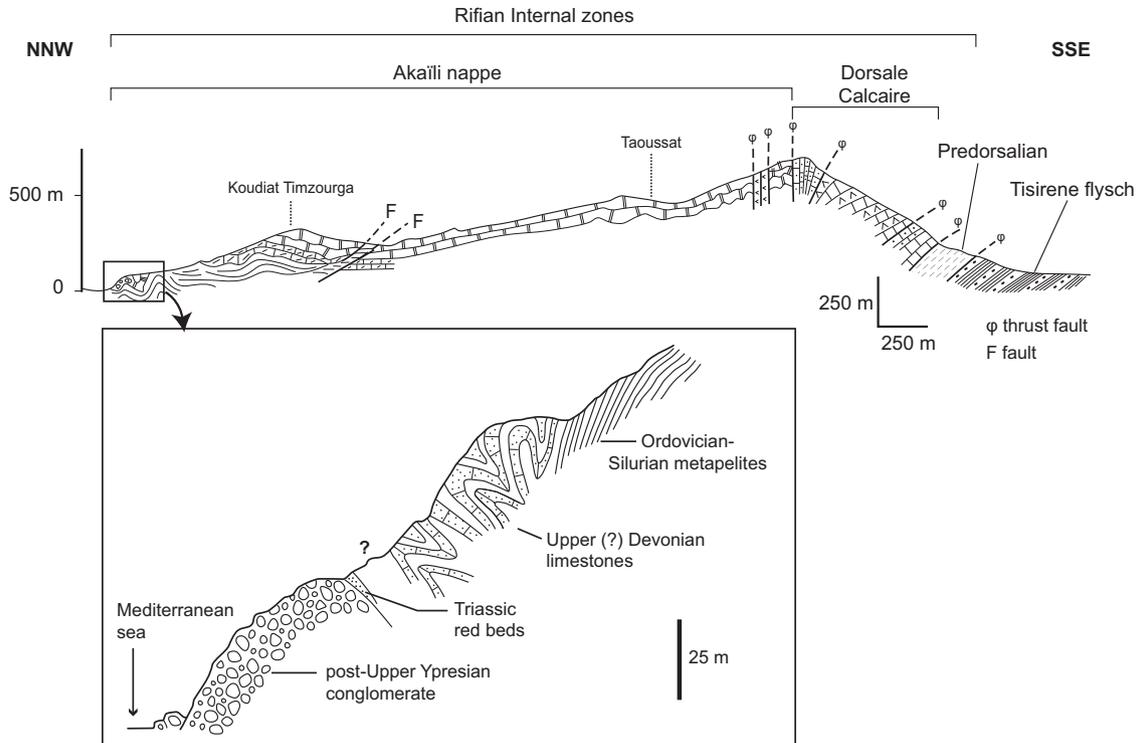


Fig. 2. Cross-section in the Internal Zones of the Rif Chain showing the position of the Jebha conglomerate.

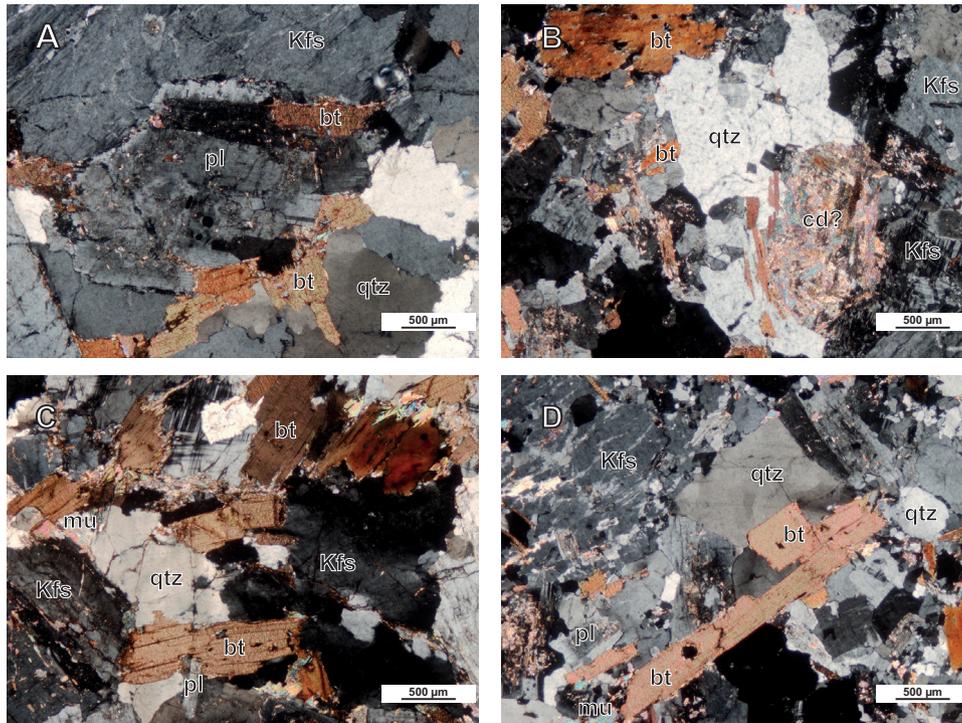


Fig. 3. Microphotographs of granites samples A: C2-4, B: CG, C: CF and D: CC from the Jebha conglomerate. Qtz: quartz; Kfs: K-feldspar; bt: biotite; mu: muscovite; cd?: cordierite pseudomorphosed into pinnite (?).

grains of tourmaline were observed in the leucogranites (samples CB and C2-2). Cordierite seems to be present as ghost crystals in some samples (CD and CG, Fig. 3B). Only the proportion of these minerals, especially K-feldspars vs. plagioclase and biotite vs.

muscovite, may vary from one sample to another. The CC sample (Fig. 3D) contains a tiny enclave (5 × 3 mm) of a rock composed of few grains of quartz, abundant more or less chloritized biotite and some grains of garnet.

All these granites display magmatic texture, with a slight sub-magmatic deformation (chess-board texture in quartz grains, but undeformed or rarely kinked micas) in some samples. No oriented fabric nor solid-state deformation was observed.

Two samples of porphyritic granites (C2-4, Fig. 3A, and CG, Fig. 3B) were geochemically analysed (ALS Chemex Labs, Vancouver, Canada) (Tab. 1). On a Shand diagram (A/NK vs. A/CNK) (Fig. 4) these samples plot in the peraluminous domain (A/CNK > 1), close to the I-type / S-type boundary (A/CNK = 1.1). On a Na₂O + K₂O vs. SiO₂ diagram (TAS diagram) (Fig. 5) these granites plot in the calc-alkaline domain.

The multi-element mantle-normalized spectra (Fig. 6a) of both samples are very similar with Ba, Nb and Sr negative anomalies. The REE patterns (Fig. 6b) are also very similar, with a clear Eu negative anomaly and a rather strong fractionation with (La/Yb)_N = 11.85 for CG and 8.88 for C2-4.

4 Age of the granite pebbles

4.1 Analytical procedure

In situ U-Th-Pb dating on zircon in thin sections of three samples of porphyritic granites, C2-4, CG and CF samples was performed by laser ablation inductively coupled plasma spectrometry (LA-ICP-MS) at Laboratoire Magmas & Volcans (Clermont-Ferrand, France). The analyses involved the ablation of minerals with a Resonetics Resolution M-50 Excimer laser system operating at a wavelength of 193 nm. Spot diameters of 26 μm were used, associated with repetition rates of 3 Hz and a laser fluence of 4 J/cm². The ablated material was carried by helium and then mixed with nitrogen and argon before injection into the plasma source of an Agilent 7500 cs ICP-MS equipped with a dual pumping system to enhance sensitivity (Paquette *et al.*, 2014). The analytical method for isotope dating is similar to that developed and reported in Hurai *et al.* (2010) and Paquette *et al.* (2017). The occurrence of common Pb in the sample was monitored by the evolution of the ²⁰⁴(Pb + Hg) signal intensity, but no common Pb correction was applied owing to the large isobaric interference from Hg. Single analyses consisted of 30 s of background integration with the laser off, followed by 60 s integration with the laser firing and a 20 s delay to wash out the previous sample and prepare for the next analysis.

Data were corrected for U-Pb fractionation occurring during laser sampling and for instrumental mass bias by standard bracketing with repeated measurements of the GJ-1 zircon reference material (Jackson *et al.*, 2004). Repeated analyses of the 91500 zircon reference material (Wiedenbeck *et al.*, 1995) treated as an unknown independently control the reproducibility and accuracy of the corrections with a concordia age of 1067 ± 3 Ma (MSWD_(C+E) = 0.45; n = 69). Data reduction was carried out with the software package GLITTER[®] from Macquarie Research Ltd (Van Achterbergh *et al.*, 2001). Calculated ratios were exported and concordia ages and diagrams were generated using the Isoplot/Ex v. 3.23 software package of Ludwig (2001). The zircon analytical results (Tab. 2) were projected on ²⁰⁷Pb/²⁰⁶Pb versus ²³⁸U/²⁰⁶Pb diagrams (Tera & Wasserburg, 1972), where the analytical points plot along a mixing line between the common

Pb composition at the upper intercept and the zircon age at the lower intercept. This method is commonly used to date Phanerozoic zircons using *in situ* techniques (Baldwin and Ireland, 1995). The concentrations of U-Th-Pb were calibrated relative to the values of the GJ-1 zircon reference material (Jackson *et al.*, 2004).

4.2 Geochronological result

Twenty-eight spots were performed on 22 zircons from the three selected samples. The analyzed zircons consist of euhedral and oscillatory zoned crystals (Fig. 7). They yield a discordia line with a lower intercept at 281.3 ± 3.2 Ma (MSWD = 0.94) (Fig. 7). No older inherited core was detected during analyses. U and Th content are often particularly high and may reach concentrations of 4400 ppm and 2660 ppm, respectively. This dating result corresponds to a Kungurian (end of the Early Permian) age.

Of course, the poorly defined ages of 85 ± 3 Ma, 174 ± 5 Ma and 194 ± 6 Ma (K-Ar on K-feldspar, on biotite and on muscovite, respectively) published by Olivier *et al.* (1979) must be considered as non-significant for the emplacement age of these granites.

5 Discussion and interpretation

The age of the Jebha conglomerate containing the granite pebbles here studied is unknown but considering the age of the foraminifer-bearing pebbles and the fact that the conglomerate was affected by folding of the Akaiïli nappe, it may be deduced that this conglomerate was deposited after the Late Ypresian and before the Late Oligocene which is the age of the first post-nappe deposits (Fnideq formation) on the Internal Zones of the Rif chain (Feinberg *et al.*, 1990). The age of folding and nappe stacking in the Ghomarides units is not precisely known but must be Latest Eocene or Oligocene in age because Upper Eocene (possibly Bartonian) marine limestones are found in the core of small synclines formed during this folding phase in the same region of Jebha (Olivier, 1990, p. 132).

The fact that many clasts from the Jebha conglomerate have decimetre-scale diameter and are poorly sorted points to a local origin and a short transport from the source areas. This hypothesis is reinforced by the fact that many pebbles display facies typical of the Ghomarides units and of the neighbouring internal Dorsale Calcaire such as the Liassic dismicrites and the alveoline- and nummulite-bearing limestones. The micaschists pebbles could be originated from the metamorphic Sebtides units though they are not characteristic. The fact that one of our granite sample contains a micro-enclave of a garnet-bearing micaschist could be an argument for an origin also from the Sebtides units, but these units have suffered a strong Alpine metamorphism, whereas the granite pebbles show no trace of such an event. The dates obtained by Olivier *et al.* (1979) on separate minerals of these granites may eventually be interpreted as an Alpine overprint, but the ages being very scattered (85, 174, 194 Ma), no precise conclusion may be drawn.

The various studies, more recent than Olivier *et al.* (1979) study, on granite pebbles from the Betic-Rif belt have been made on samples of conglomerates belonging to the marine

Table 1. Major and trace elements analyses of C2-4 and CG granite samples (this study) and of granite pebbles studied by [Gigliuto et al. \(2004\)](#).

Provenance Sample	This study		Gigliuto et al. (2004)						
	Jebha conglomerate		Beni Ider flysch				Ghomarides cover		
	C2-4	CG	Vu4	CR1	AC8	AC22	BM12	CR8	CR10
SiO ₂	72.3	72.2	72.72	72.66	74.11	73.44	77.93	72.23	71.49
Al ₂ O ₃	14.3	13.5	14.21	14.29	14.22	13.67	12.06	14.68	14.48
Fe ₂ O ₃	1.84	1.79	1.7	1.58	0.69	2.17	0.42	1.93	1.93
CaO	1.2	0.82	0.87	0.73	0.56	0.73	0.38	1.09	1.04
MgO	0.46	0.54	0.52	0.41	0.19	0.56	0.13	0.63	0.61
Na ₂ O	3.57	3.22	2.79	2.83	3.29	2.98	3.49	3.13	2.99
K ₂ O	4.7	4.49	5.02	5.29	5.69	4.76	4.88	4.58	4.82
Cr ₂ O ₃	< 0.01	< 0.01							
TiO ₂	0.23	0.26	0.16	0.2	0.13	0.3	0.05	0.26	0.28
MnO	0.03	0.03	0.02	0.02	0.01	0.03	0.01	0.02	0.02
P ₂ O ₅	0.13	0.19	0.2	0.15	0.23	0.18	0.02	0.17	0.17
LOI	0.51	0.99	1.77	1.26	0.82	1.15	0.65	1.36	1.26
Total	99.27	98.03	99.98	99.42	99.94	99.97	100.02	100.08	99.09
Ag	< 0.5	< 0.5							
As	1.6	1.3							
Ba	252	286	256	296	253	170	122	249	279
Bi	0.24	11.8							
Cd	< 0.5	< 0.5							
Co	113	135							
Cr	< 10	< 10							
Cs	15.65	10.95	36.9	32.3	11.9	30.7	0.9	22.3	21.4
Cu	4	13							
Ga	20.1	21.3	20	21	16	20	19	19	19
Hf	3.8	4.3	2.9	3.6	2	3	3.7	3.3	3.3
Hg	0.194	0.222							
Li	80	50							
Mo	< 1	< 1							
Nb	9.3	12	12	15	15	14	14	12	12
Ni	6	4							
Pb	50	35							
Rb	250	276	318	310	300	289	125	257	267
Sb	< 0.05	0.13							
Sc	3	4	2	3	2	5	3	4	4
Se	< 0.2	0.4							
Sn	8	22	17	18	12	9	3	9	8
Sr	87	84.6	128	130	88	52	34	101	102
Ta	1.5	1.7	2.7	3	3.9	1.9	3.8	1.9	1.9
Te	< 0.01	0.13							
Th	13.45	13.55	9.8	12.8	4.9	11.4	19	12	12.5
Tl	1.2	1.2							
U	2.34	2.24	3.1	3.8	1.8	2.3	2.2	2.2	2.2
V	13	15							
W	563	668							
Y	19.7	18	12	16	5	20	48	11	11
Zn	109	22							
Zr	134	129	103	126	57	106	74	118	115
La	21.9	29.9	19.1	27.9	9.4	22.8	14	21.2	22.4
Ce	47.6	70.7	37.7	54.9	19.5	47.8	44.9	44.3	49.3
Pr	5.36	8.45							

Table 1. (continued).

Provenance Sample	This study		Gigliuto <i>et al.</i> (2004)						
	Jebha conglomerate		Beni Ider flysch				Ghomarides cover		
	C2-4	CG	Vu4	CR1	AC8	AC22	BM12	CR8	CR10
Nd	21.4	33.1	15.9	23.3	8.1	21.4	14.4	19.8	21.5
Sm	4.23	6.89							
Eu	0.62	1.06	0.5	0.58	0.49	0.46	0.13	0.54	0.57
Gd	3.47	4.71							
Tb	0.59	0.68	0.4	0.6	0.3	0.7	1.1	0.4	0.5
Dy	3.45	3.64							
Ho	0.7	0.69							
Er	2.06	1.65							
Tm	0.27	0.26							
Yb	1.77	1.81							
Lu	0.36	0.28	0.14	0.23	0.07	0.27	0.68	0.15	0.15

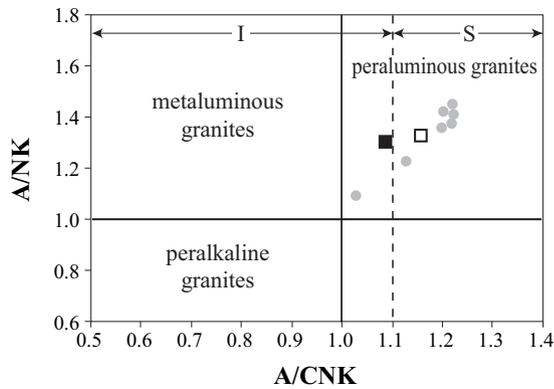


Fig. 4. A/NK vs. A/CNK diagram for the granites C2-4 (black square) and CG (white square) of this study, and for the granites (grey circles) studied by Gigliuto *et al.* (2004).

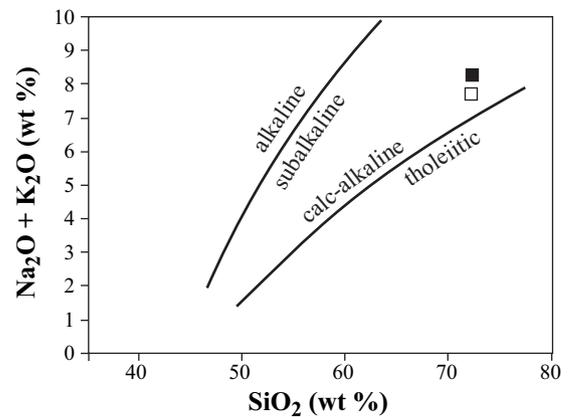


Fig. 5. Na₂O + K₂O vs. SiO₂ diagram for the granites C2-4 (black square) and CG (white square).

Upper Oligocene-Lower Miocene post-nappe cover of the Ghomarides (Fnideq formation) (Martín-Algarra *et al.*, 2000; Puglisi *et al.*, 2001; Zaghoul *et al.*, 2003; Gigliuto *et al.*, 2004) and of the Malaguides (Ciudad Granada formation) (Martín-Algarra *et al.*, 2000), and from Upper Oligocene conglomerates of the Beni-Ider flysch (internalmost flysch nappe) (Puglisi *et al.*, 2001; Gigliuto *et al.*, 2004). Most of the granites studied by these authors are two-mica cordierite-bearing monzogranites and leucogranites, comparable to our samples, probably indicating a same origin, but only Gigliuto *et al.* (2004) have published chemical analysis of these rocks. Their compositions are remarkably similar, both for the major and trace elements, to the compositions of the granite pebbles from the Jebha conglomerate (Tab. 1). It just may be noted that most samples of Gigliuto *et al.* are slightly more peraluminous (Fig. 4). All these authors have admitted a local provenance (Ghomarides-Malaguides domain) of most pebbles from these conglomerates but the fact that granites and other rocks, such as orthogneiss, are unknown or poorly represented in the presently outcropping units led some of these authors to propose other origins for the granites. For Martín-Algarra *et al.* (2000), it could be a “lost realm” located to the east or south-

east of the present Betic-Rif belt and similar to the crystalline basement of the Kabylia-Calabria-Peloritani domain. A similar hypothesis was proposed by Puglisi *et al.* (2001). Conversely Gigliuto *et al.* (2004) exclude, on the basis of differences in Rb, Sr and Ba contents, the possibility of correlating the analysed granitoids with the plutonic rocks of the Calabria-Peloritani Arc and of the Kabylia massifs. They favour an origin of the granite pebbles in the Iberian Massif (central Spain and northern and central Portugal). Only Zaghoul *et al.* (2003) consider that all the pebbles were originated from the Ghomarides domain.

The 281 Ma age of the granite pebbles from the Jebha conglomerate presented in this paper allows us to better discuss these hypothesis. Most of the granites from the Iberian Massif (*e.g.*, Alvarado *et al.*, 2013 and references therein), but also from the Moroccan Meseta (*e.g.*, Michard *et al.*, 2008 and references therein), and from the Calabria-Peloritani domains (*e.g.*, Fiannacca *et al.*, 2008) are Middle and Late Carboniferous to Earliest Permian in age, whereas granites as recent as 280 Ma have been rarely characterized in these domains. However, Peucat *et al.* (1996) have dated at 278 ± 3 Ma (U/Pb on zircon) the Collo two-mica sillimanite-

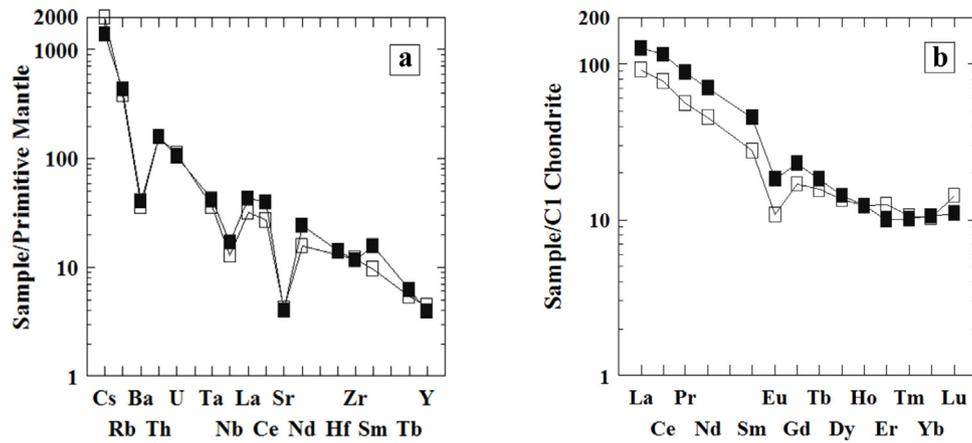


Fig. 6. a. Multi-element patterns normalized to the primitive mantle (Wood *et al.*, 1979) for the granites C2-4 (black square) and CG (white square). b. REE patterns normalized to chondrite (Sun and McDonough, 1989) for the granites C2-4 (black square) and CG (white square).

Table 2. LA-ICPMS U-Pb zircon dating results.

sample	zircon#	Pb ppm ^a	Th ppm ^a	U ppm ^a	Th/U	²⁰⁷ Pb/ ²³⁵ U ^b	2 σ error		Rho	Age (Ma)	2 σ error	
							²⁰⁷ Pb/ ²³⁵ U	²⁰⁶ Pb/ ²³⁸ U ^b			²⁰⁶ Pb/ ²³⁸ U	²⁰⁶ Pb/ ²³⁸ U
C24F	C1/Zr1	103	222	2351	0.09	0.4131	0.0151	0.04457	0.00153	0.94	281.1	9.5
C24F	C1/Zr2	159	2656	2946	0.90	0.3955	0.0152	0.04462	0.00156	0.91	281.4	9.5
C24F	C4/Zr1	144	454	3408	0.13	0.4060	0.0165	0.04283	0.00150	0.86	270.3	9.2
C24F	C5/Zr1.1	32	76	746	0.10	0.3618	0.0148	0.04505	0.00156	0.85	284.1	9.7
C24F	C5/Zr1.2	29	74	669	0.11	0.3531	0.0137	0.04481	0.00156	0.90	282.6	9.6
C24F	C5/Zr1.3	36	149	826	0.18	0.3573	0.0140	0.04504	0.00156	0.89	284.0	9.6
C24F	C5/Zr1.4	33	131	758	0.17	0.3420	0.0134	0.04499	0.00156	0.89	283.7	9.6
C24F	C5/Zr2	155	295	3524	0.08	0.4418	0.0163	0.04499	0.00156	0.94	283.7	9.6
C24F	C9/Zr1.1	153	253	3547	0.07	0.4017	0.0158	0.04428	0.00153	0.88	279.3	9.5
C24F	C9/Zr1.2	55	79	1192	0.07	0.4901	0.0206	0.04525	0.00159	0.84	285.3	9.8
C24F	C10/Zr1	92	847	2002	0.42	0.3254	0.0128	0.04498	0.00156	0.89	283.6	9.6
C24F	C10/Zr2	71	340	1621	0.21	0.3243	0.0127	0.04512	0.00156	0.88	284.5	9.7
C24F	C10/Zr3	202	1309	4430	0.30	0.4030	0.0154	0.04472	0.00156	0.91	282.0	9.6
C24F	C13/Zr1	50	331	1059	0.31	0.4074	0.0254	0.04441	0.00165	0.60	280.1	10.1
CF Rif	C5/Zr1	59	44	1336	0.03	0.4285	0.0174	0.04563	0.00171	0.92	287.6	10.5
CF Rif	C8/Zr1	92	307	2177	0.14	0.3185	0.0121	0.04406	0.00162	0.97	278.0	10.1
CF Rif	C9/Zr1.1	42	153	1004	0.15	0.3767	0.0148	0.04331	0.00162	0.95	273.3	9.9
CF Rif	C9/Zr1.2	79	170	1832	0.09	0.3528	0.0141	0.04527	0.00168	0.93	285.4	10.4
CF Rif	C11/Zr1	38	126	877	0.14	0.3317	0.0133	0.04502	0.00168	0.93	283.9	10.3
CF Rif	C12/Zr1	73	105	1771	0.06	0.3390	0.0149	0.04344	0.00162	0.85	274.1	10.0
CG Rif	C2/Zr1	74	416	1674	0.25	0.3613	0.0144	0.04413	0.00162	0.92	278.4	10.1
CG Rif	C3/Zr1	20	107	443	0.24	0.3673	0.0180	0.04571	0.00171	0.76	288.2	10.6
CG Rif	C5/Zr1	113	539	2609	0.21	0.3885	0.0147	0.04390	0.00162	0.97	277.0	9.9
CG Rif	C7/Zr1	86	625	1967	0.32	0.3234	0.0125	0.04317	0.00159	0.95	272.5	9.8
CG Rif	C8/Zr1	77	285	1713	0.17	0.4054	0.0159	0.04513	0.00165	0.93	284.5	10.2
CG Rif	C10/Zr1	26	201	568	0.35	0.3432	0.0142	0.04488	0.00165	0.89	283.0	10.1
CG Rif	C10/Zr2	22	304	427	0.71	0.3801	0.0167	0.04529	0.00168	0.85	285.6	10.3
CG Rif	C13/Zr2	76	210	1850	0.11	0.3658	0.0144	0.04342	0.00156	0.91	274.0	9.7

Decay constants of Jaffrey *et al.* (1971) used.

^a: concentration uncertainty c.20%.

^b: data not corrected for common-Pb.

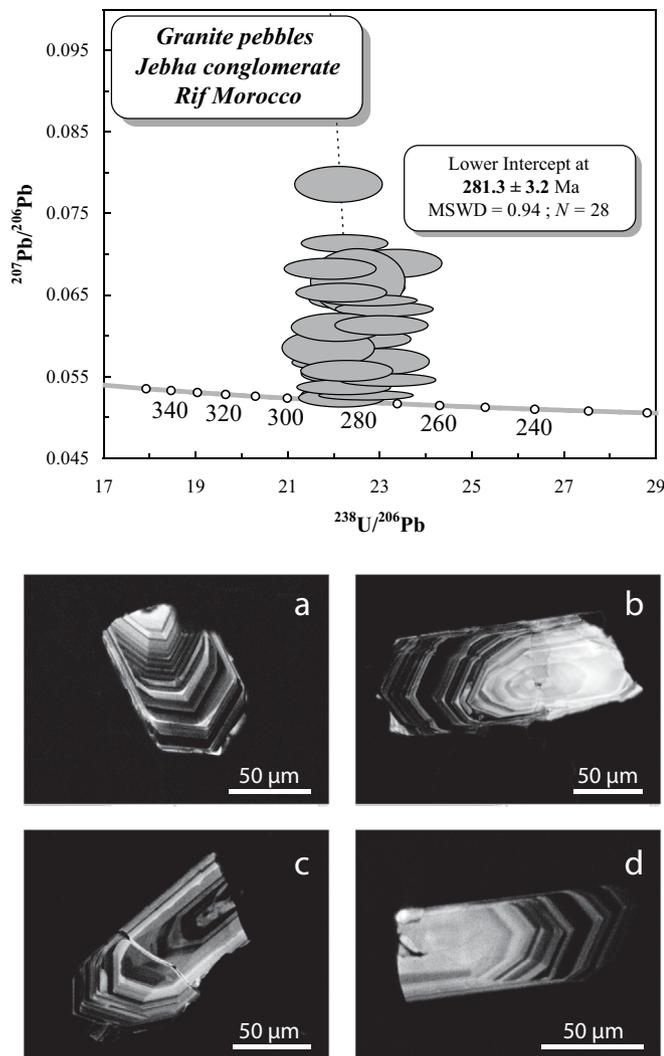


Fig. 7. $^{207}\text{Pb}/^{206}\text{Pb}$ vs. $^{238}\text{U}/^{206}\text{Pb}$ Concordia diagram for the granite samples C2-4, CF and CG from the Jebha conglomerate. Microphotographs of representative zircons from C2-4 (a and b), CF (c) and CG (d).

bearing granite belonging to the upper units (greenschist facies) of the Internal domain of Lesser Kabylia, more or less equivalent to the Ghomarides units, and a dioritic enclave in the Sidi Ali Bou Nab granite of Great Kabylia at 284 ± 3 Ma. Enrique and Debon (1987) have dated the Montnegre granitic pluton, in the Catalan Coastal Ranges, at 269 ± 4 Ma, whereas Solé *et al.* (2002) have obtained on the same pluton a cooling age at 285 ± 3 Ma but these ages obtained respectively by Rb-Sr on whole rock and $^{40}\text{Ar}/^{39}\text{Ar}$ on biotite techniques would need to be confirmed by an U-Pb on zircon dating. Granites dated at about 280 Ma are also known in Corsica (e. g. Paquette *et al.*, 2003; Renna *et al.*, 2007; Rossi *et al.*, 2015) which could have been located close to the northeastern part of the AlKaPeCa domain (*i.e.*, Calabria) (Rosenbaum *et al.*, 2002) before the opening of the Alboran sea and Algerian and Provençal basins from the Early Miocene onwards. Farther from the Alboran domain Permian granites are known in the internal Alps, especially in the Sesia zone (Manzotti *et al.*, 2014).

We have shown above that the numerous and large granite clasts of the Jebha conglomerate have certainly a local origin. Owing to their Kungurian age, these granites may be only compared to few granites from neighbouring regions (eventually Kabylia and Catalan Coastal Ranges), 280 Ma old granites being mainly known in regions farther from the Rif (Corsica, Internal Alps), if one considers the former positions of the continents during the Eocene-Oligocene time. Consequently, we must admit that a large calc-alkaline granite pluton emplaced by the end of the Early Permian was outcropping during the Middle Eocene–Oligocene, and eventually during the Early Miocene, in a Ghomaride unit but that this unit was drowned in the Alboran sea during the Miocene opening of this basin. Until now, Variscan granites have not been found off-shore of the Betic-Rif belt, but high-grade metamorphic rocks similar to those of an Apujarride unit, associated with 22–19 Ma old granites, were cored at site 976 of Leg 161 (60 km south of Malaga) (Sánchez-Gómez *et al.*, 1999), showing that at least a part of the floor of the Alboran basin is constituted by rocks of continental origin. It is thus very likely that other sites of the Alboran sea are constituted by Ghomarides-Malaguides-like units indicating that this domain is much larger than the on land outcropping zones and that a granite pluton could be present not far from the Rifian coast.

6 Conclusion

This first reliable date of granites from the Rifian internal zones presented in this paper represents a strong constraint for determining the origin of these granites. This result also shows that an important episode of plutonism occurred very late in this part of the Variscan domain. This plutonism was calc-alkaline and not alkaline contrary to most Permian plutonic rocks of the Variscan orogen (*e.g.*, Denèle *et al.*, 2012; Vacherat *et al.*, 2017), probably characterizing an original domain in this orogen. Further studies will have to take these facts into account, but new datings on granite pebbles from the Betic-Rif belt and other part of the same chain (for instance in the Kabylia), and from outcropping granites of neighbouring regions (Moroccan meseta) where granites are often poorly dated, will be necessary to better characterize the end of the Variscan evolution of this orogenic domain. Another crucial problem, the exhumation age of the Rifian granites, would need to be studied by low-temperature thermochronology.

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