Dating of hydrothermal events in the Sierra del Guadarrama, Iberian Hercynian Belt. Spain

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ABSTRACT

Preliminary results are presented on the age of the hydrothermal activity recorded in the Sierra del Guadarrama. They are among the first data generated by the K-Ar Spectrometry Lab. of the CSIS-UCM at Madrid. Hydrothermalites include different types of lodes (W, W-Sn, As, Cu, Pb-Zn, barren quartz, among others), greisens, skarns, episyenites and quartz-chlorite-sericite replacements. Recorded activity spans from ca. 300 to 100M.a. with five well defined «Peaks»: 1) 300-290M.a. (greisens and many W lodes), 2) 267 M.a (W-lode related to porphyry dykes), 3) 260-220M.a. (Fe-(Ca) skarn and episyenites), 4) 151-156M.a. (quartz-chlorite-sericite replacements, i.e. phyllic alteration), and 5) 100M.a. (long barren quartz lodes related to strike-slip faults). This episodic activity is temptatively correlated with important geotectonic events involving the Iberian Peninsula.

RESUMEN

Se presentan los resultados preliminares de la datación de la actividad hidrotermal en la Sierra de Guadarrama, obtenidos en el laboratorio de Espectrometría K-Ar del CSIC-UCM en Madrid. Los productos de la actividad hidrotermal incluyen distintos tipos de filones (W, W-Sn, As, Cu, Pb-Zn, cuarzo estéril, entre otros), greisens, skarns, episienitas y reemplazamientos por cuarzo-clorita-sericita. La actividad registrada se extiende desde casi 300 hasta los 100M.a. con cinco «picos» bien definidos: 1) 300-290M.a. (greisens y la mayoría de los filones de W), 2) 267M.a. (filón de W relacionado con diques de pórfido), 3) 260-220M.a. (skarn de Fe-(Ca) y episienitas), 4) 151-156M.a. (alteraciones filíticas=remplazamientos por cuarzo-clorita-sericita) y 5) aprox. 100M.a. (filones de cuarzo estéril en relación con fallas de desgarre). Esta actividad episódica se correlaciona tentativamente con importantes eventos geotectónicos en los que se vio implicada la Península Ibérica.

Key words: *Hydrothermal alteration, Geocrhonology, K/Ar dating, Sierra del Guadarrama.*

Geogaceta, 11 (1992), 18-22.
ISSN: 0213683X

Introduction

Preliminary results are presented here on the geochronology of the hydrothermal activity in the Sierra del Guadarrama (Spanish Central System). They are among the first data generated by the K-Ar laboratory of the CSIC-UCM at Madrid.

Hydrothermal alterations and lodes are widespread in the Sierra del Guadarrama although economic importance is for the moment minor. They always show a strong structural control following fracture systems that repeat from one hydrothermal event to the other.

Geological Setting

The Sierra del Guadarrama is a part of the Iberian hercynian basement and consists for the most part of granites and high- grade metamorphic rocks, mostly pre-Hercynian orthogneisses and some metasediments. A set of swarms of E-W dykes is also a notable feature of this part of the Spanish Central System.

Granites are late-Hercynian rocks and form the Guadarrama batholith. They were emplaced in the age range

345-275 m.a. (Vialette *et al.*, 1981; Ibarrola *et al.*, 1987), following the Hercynian orogenic phases. They consist for the most part of peraluminous adamellites to leucogranites. Earlier minor bodies of quartz- diorites to tonalites are also found as well as younger massifs of amphibole-bearing adamellites and granites with a monzonitic affinity (Fuster & Villaseca, 1987; Casillas & Peinado, 1987).

Dyke swarms consist for the most part of adamellite to leucogranite porphyries and minor microdiorites and diabases (Huertas, 1986). Most of them, show an E-W strike, a length of several tens of kilometers and a regular spacing between swarms. Small cupulas of porphyries with asociated W-quartz lodes and greisens are locally found along these swarms. The age of these dykes is still unknown.

All these rocks forming the Sierra del Guadarrama occupy the lower plate of a large core complex-like structure developed during late-Hercynian times (Casquet *et al.*, 1988), which is also the site of most of the hydrothermal activity visible in this segment of the Spanish Central System. Repeated fracture reactivation of the basement probably took place place several times during Mesozoic and Cainozoic times. However, most of this tectonic history is for the moment poorly documented.

Hydrothermal Manifestations

The following types of hydrothermal formations can be distinguished (see also Locutura and Tornos, 1985):

1. *Magmatic and postmagmatic stage skarns.*
   1.A.–W.
   1.B.–W-Sn.
   1.C.–W-Sn-Cu-Zn-(Bi-Ag).
   1.D.–Fe-(Sn).
2. *Sn-(W) greisens.*
3. *Episyenites.*
   3.A.–Bt-microclinites.
   3.B.–Cpx (±amph) albitites.
   3.C.–Amph (±epid) albitites.
   3.D.–Chlor (±epid) albitites.
4. *Quartz-chlorite-sericite alterations.*
5. *Lodes.*
   5.A.–W± (Sn-Mo) quartz.
   5.B.–Sn-quartz.
   5.C.–Cu-As-(W-Sn-Bi-Pb-Zn-Ag)-quartz.
   5.D.–Pb-Zn-barite-fluorite.
   5.E.–Barren quartz.

Episyenites are de-quartzified and alkalinized granites and to a lesser extent gneisses. They are commonly pink-colored rocks that were formed by the action of hydrothermal fluids along well defined E-W, and to a lesser extent N-S fracture zones. Petrographical features of these rocks in this area have been summarized by Caballero *et al.* (1990).

Selection of samples and analytical procedure

This study has been carried out on the following hydrothermal types: 1D, 2, 3 (A, B and C), 4, 5 (A, C and E). In all the cases mineral concentrates of moscovite-sericite, biotite or amphibole have been employed for the analysis. Ar analysis were performed on the on-line Micromass 6 mass spectrometer of the Instituto de Geologia Economica of Madrid and the UCM. Accuracy of the system was assessed by analysis of several standard materials. Potassium was determined in replicate by conventional acid decomposition and atomic absorption spectrometry. Results with location of the samples are displayed in Table 1. The calculated errors (quoted at 2σ) on the ages, are typically about ±2% depending on the degree of error in the determination of radiogenic argon, due to the presence of small amounts or atmospheric argon.

Results

The results of this work are still preliminary as not all the hydrothermal types have been dated yet. However some interesting conclusions can already be drawn.

1. The ages found range from ab 300 to 100 m.a. Five well defined period of hydrothermal activity are recorded:

P_1) 302-290 M.a. (i.e. Upper Carboniferous), corresponding to most W-lodes and greisens.

P_2) 267 M.a. (i.e. Lower Permian), corresponding to a W-quartz lode in a small cupula related to a dyke swarm (Navalcubilla) (Tornos, 1990).

P_3) 260-220 M.a. (i.e. Upper Permian to Upper Triassic), corresponding to the episyenites. Younger ages are found in episyenites where lower temperature overprints (phyllitic and argillic alterations) seem to be more important. An age of 259 M.a. corresponds to a Fe (Magnetite)-Ca-skarn (El Caloco), that replaces an E-W porphyry dyke (Tornos, 1990).

P_4) 151-156 M.a. (i.e. Upper Jurassic), corresponding to the quartz-chlorite-sericite phyllitic alteration.

P_5) c. 100 M.a. (i.e. Lower Cretaceous), corresponding to quartz lodes filling dilatancy zones along NE-SW strike-slip faults. The determination was carried out on the sericite of the phyllitic alteration on the host granite.

Discussion

These results lead us to the following conclusions:

1. The hydrothermal activity recorded in the Sierra del Guadarrama is only in part late-Hercynian in age (greisens and W-lodes of the P_1 period) and probably related to the peraluminous plutonism. However, most of the hydrothermal activity is clearly younger than the youngest age recorded up to this date in the Guadarrama batholith (275 M.a.). Thus, an importante part of the hydrothermal history is not related to the late-Hercynian plutonism as opposite to previous views.

2. The hydrothermal activity is episodical. Taking into account its strong structural control we can suggest that the hydrothermal peaks represent true periods of fracture formation and/or reactivation of the crystalline basement. For the post-Hercynian activity, these peaks have been correlated with major tectonic events as deduced from the sedimentary record in neighbouring areas, e.g. The Iberian realm (Ziegler, 1988; Sopeña *et al.*, 1988). The following correlation is proposed:

A) the first peak can be related with the late-Hercynian extensional tectonics, likewise responsable to a large extent for the emplacement of the granitic magmas (Casquet *et al.*, 1988).

B) The second peak could be correlated either with the end of the

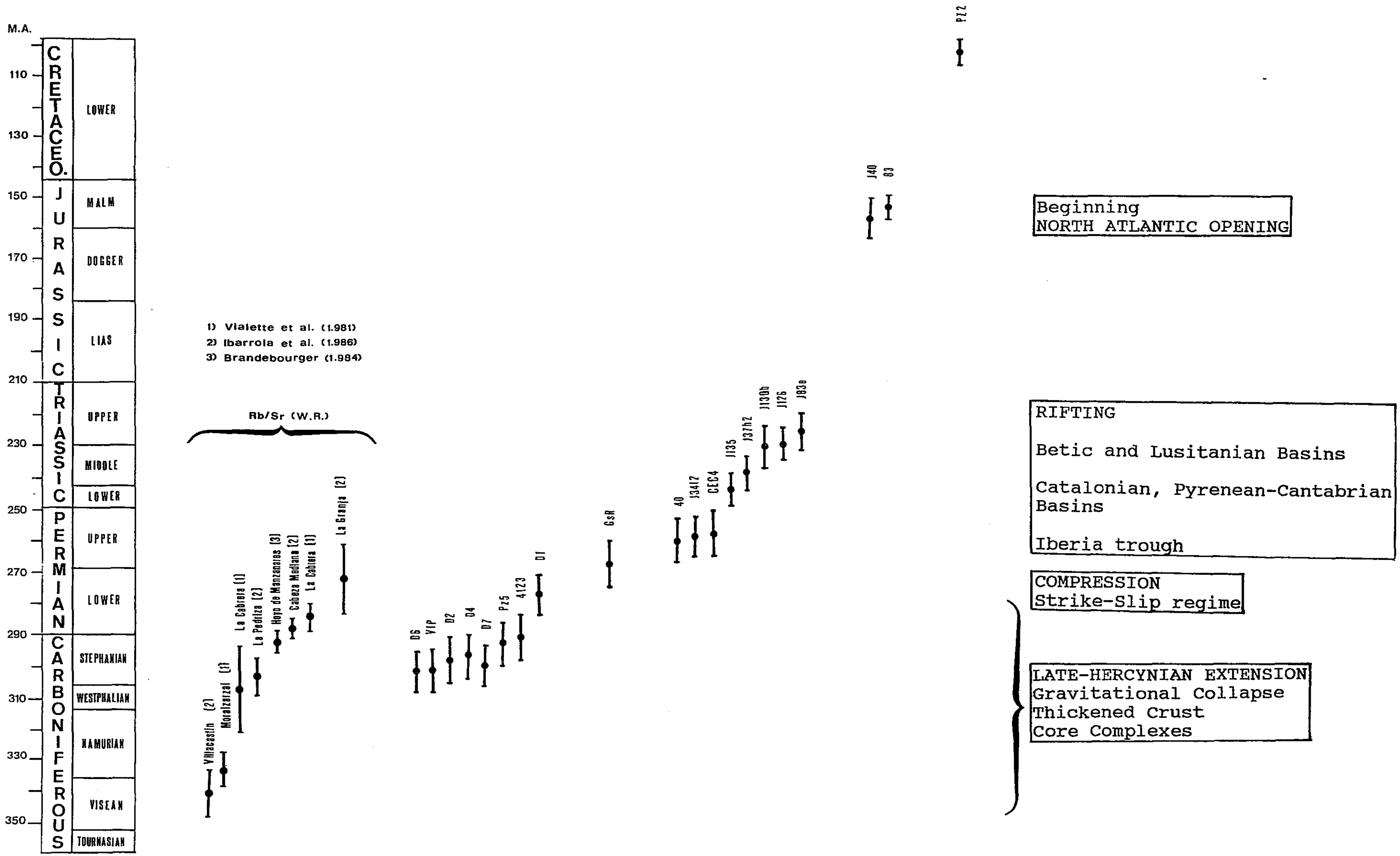

Fig. 1.—Ages of hydrothermal rocks in the Sierra del Guadarrama. Aproximated time span of important geotectonic events, as well as Rb-Sr ages of granitoids are also included for comparison. Time scale after Harland *et al.* (1982).

Fig. 1.—Edades de las rocas hidrotermales en la Sierra del Guadarrama. Se incluye también la edad aproximada de eventos geotectónicos importantes, así como las dataciones Rb-Sr de varios granitoides. Escala cronológica, según Harland et al. (1982).

compressional phase responsable for the long strike-slip faults controlling the Upper Carboniferous - Lower Permian sedimentation (Arthaud and Matte, 1977), or the beginning of rifting leading to the opening of the Iberian trough. This should also be the age of the dyke injection represented at least by the E-W swarms.

C) The third peak is clearly synchronous with the aforementioned rifting phase, and further extensional reactivations of the basement during the opening of the Pyrenean-Cantabrian, Betic and the Lusitanian Basins, in this order.

D) The fourth peak is likely related to the beginning of the opening of the Nort Atlantic.

E) Finally the fifth peak sould be linked to a poorly known Middle Cretaceous compressional (?) phase. It coincides with ages found also in the Cameros Basin (Iberian Range) for and hydrothermal very low grade metamorphism related to a deformation band (Casquet *et al.* this volume).

Acknowledgements

This work is a part of a research project financed by the spanish CICYT (grant PB 88-0124). We are indebted to E. Vindel and E. Quilez who provided some of the samples.

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Recibido el 1 de octubre de 1991
Aceptado el 25 de octbre de 1991

Pregunta de J. Lillo Ramos:

1ª pregunta: ¿Se ha considerado la posibilidad que algunas de las edades radiométricas obtenidas estén en relación con la emersión o levantamiento del Sistema Central más que ser indicativas de eventos hidrotermales?

2ª pregunta: ¿Es posible que haya existido un «resetting» o modifica-

Tabla 1.—**K-Ar ages of hydrothermal rocks in the Sierra del Guadarrama**

*Tabla 1.—**Edades K-Ar de rocas hidrotermales de la Sierra del Guadarrama***

Sample Nº	Mineral	%K	%atm. Ar	rad.Ar (nl/gr)	AGE M.A.	Location
D6	Ms	7.983	4.80	101.90	301.7 ± 6.4	W-Cu lode. El Estepar (San Rafael)
D2	Ms	8.425	4.44	106.00	297.8 ± 6.4	W-lode. Cabeza Lijar (Guadarrama)
D4	Ms	8.332	11.24	104.00	295.7 ± 6.9	W-lode. Cabeza Lijar (Guadarrama)
D1	Ms	8.520	9.11	99.19	277.0 ± 6.2	W-lode. Cabeza Lijar (Guadarrama)
VIP	Ms	8.628	12.26	110.10	301.6 ± 6.8	W-lode. Cabeza Lijar (Guadarrama)
D7	Ms	7.959	3.13	100.81	299.7 ± 6.4	W-lode. Garganta de los Montes
4123	Ms	8.656	22.11	69.61	290.8 ± 7.1	Greisen. La Navata
Pz5	Ms	8.434	7.79	104.10	292.5 ± 6.6	Greisen. Parquelagos (Torrelod.)
GsR	Ms	6.815	8.59	76.21	267.1 ± 7.4	W-lode. Navalcubilla (Otero de H.)
40	Amph	1.807	11.97	10.30	258.6 ± 7.0	Fe-(Ca) skarn. El Caloco
J83e*	Amph	1.073	2.80	9.97	224.6 ± 6.0	Episyenite. Manzanares el Real
J130b	Amph	0.963	15.10	9.17	230.0 ± 6.5	Episyenite. Galapagar
J34f2	Amph	1.227	14.52	13.24	258.3 ± 5.9	Episyenite. Becerril
J126	Bt	7.026	5.80	68.09	223.7 ± 5.1	Episyenite. Cerceda
J135	Bt	8.434	2.37	85.37	243.4 ± 5.2	Episyenite. El Escorial
J37H2	Bt	5.542	4.44	54.40	236.5 ± 5.5	Episyenite. Navacerrada
CEC-4	Bt	7.27	24.86	78.29	256.9 ± 6.8	Episyenite. Manzanares el Real
J40	Seric	9.337	36.57	58.96	156.0 ± 6.0	Phyllic alter. Cercedilla
83	Seric	9.040	10.50	55.54	151.6 ± 4.0	Phyllic alter. Otero de Herreros
Pz2	Seric	5.458	34.38	21.94	100.6 ± 4.3	Phyllic alter. Q lode. Parquelagos

Decay constants: $\beta = 4.963 \pm 10^{-10} a^{-1}$, $e = 0.581 \cdot 10^{-10} a^{-1}$, 40K = 0.01167 atom%.

ción sobreimpuesta de las edades originales de las micas en algunas de las alteraciones comentadas, dando así edades aparentes más modernas que la edad real de la alteración?

Respuesta de los autores:

1. La actividad hidrotermal datada está relacionada con el rejuego de sistemas de fracturas regionales. El tipo de funcionamiento de las mismas no ha sido considerado en este trabajo, aunque la existencia de una componente vertical de movimiento es muy frecuente en ellas. Por otro lado, el hecho de que cada uno de los eventos datados tenga una paragénesis hidrotermal característica parece excluir la posibilidad implícita en la pregunta.

2. La existencia de un cierto «re-setting» de las edades K-Ar parece tener cierta importancia en las episienitas, como de hecho mencionamos en el texto; particularmente en biotitas y anfíboles. En el caso de la moscovita y sericita, no tenemos evidencia de reajustes significativos, al menos en la mayoría de los casos estudiados; además, las edades obtenidas son consistentes con la secuencia cronológica observada en el campo.