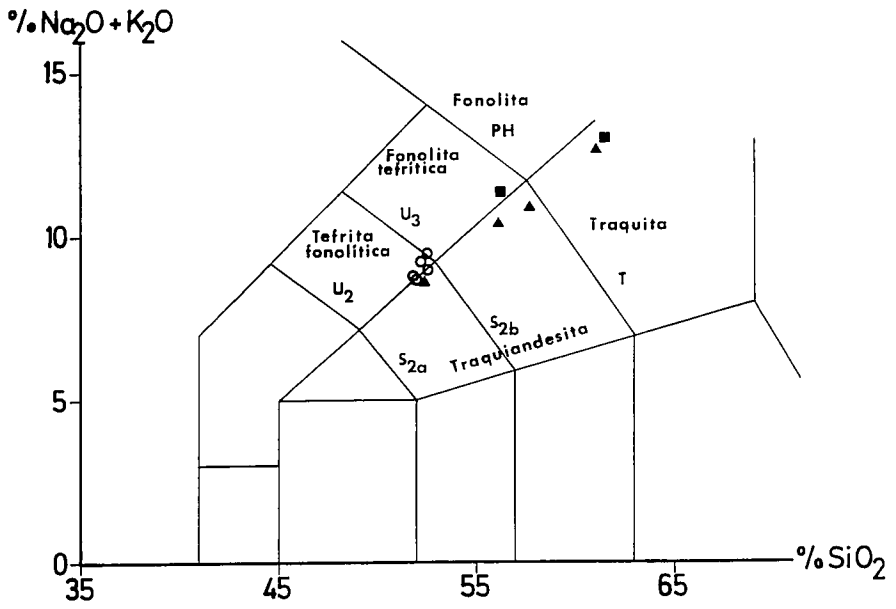

Fig. 3.—Diagrama TAS en el que se representan coladas y escorias del volcán de Taco, así como niveles pumíticos (Araña *et al.*, 1986 —triángulos—; y Fúster *et al.*, 1968 — cuadrados—).

Fig. 3.—TAS plot of socriae and lava flows of Taco volcano, pumice analyses from Araña et al. (1986) (triangles) and Fuster et al (1968) (squares) are included.

Agradecimientos

Este trabajo ha sido financiado por la Consejería de Educación del Gobierno de Canarias (proy., 6/2-6-87)

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Recibido el 20 de enero de 1992
Aceptado el 21 de febrero de 1992

New data on the Spherules from the Cretaceous-Tertiary Boundary Layer at Caravaca (SE Spain)

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ABSTRACT

The spherules from the K/T boundary layer in the Caravaca sequence are made up of Kfs ($Si_{3,03}$ $O_8Al_{1,03}K_{0,93}$ $Na_{0,01}$) presenting fibroradial and dendritic textures. These textures have been interpreted as being directly derived from a supposed extraterrestrial impact (Smit & Klaver, 1981). Montanari (1983) considered that the Kfs had diagenetically replaced a precursor mineral. This paper presents the first data obtained from analyses carried out on the nuclei of the Kfs spherules, which represent the precursor mineral and correspond to a mafic-type composition (SiO_2 = 56 %; Al_2O_3 = 10 %; MgO = 8.5%; FeO = 13%; CaO = 3%; Na_2O = 2%; K_2O = 0.9%). Their present state of preservation allows us to suggest that the precursor mineral is an amphibole possibly derived by alteration from a pyroxene.

RESUMEN

Las esférulas de la lámina de sedimento que marca el tránsito K/T en Caravaca están compuestas de Kfs prácticamente puro ($Si_{3,03}$ $O_8Al_{1,03}K_{0,93}$ $Na_{0,01}$) con texturas fibroradiales y dendríticas. Inicialmente fueron interpretadas como derivadas directamente de un supuesto cuerpo extraterrestre (Smit y Klaver, 1981). Por el contrario, Montanari (1983) considera que el Kfs ha reemplazado diagenéticamente a un mineral precursor. En este trabajo se presentan los primeros datos de análisis realizados en algunos núcleos de las esférulas de Kfs, que constituyen el precursor de las mismas y que responden a una composición de tipo máfico: (SiO_2 = 56 %; Al_2O_3 = 10 %; MgO = 8.5%; FeO = 13%; CaO = 3%; Na_2O = 2%; K_2O = 0.9%). Su estado actual de preservación nos permite sugerir que el mineral precursor es un anfibol derivado de la alteración de un piroxeno.

Geogaceta, 12 (1992), 30-32.
ISSN: 0213683X

Introduction

The discovery of Ir anomalies (Alvarez *et al.*, 1980) in the sediments of the CretaceousTertiary boundary has led to an extended debate on the possible cause of the great faunal extinction marking the end of the Cretaceous. As well as the high iridium content, which is generally considered to be proof of extraterrestrial contamination, these sediments are also found to contain spherules whose origin is highly controversial. The spherules, composition basically corresponds to Kfs (Smit & Klaver, 1981; Martínez Ruíz *et al.*, 1992), Fe oxides (Brooks et al., 1985; Martínez Ruíz et al., op.cit.), glass (Sigurdsson *et al.*, 1991) or glauconite (Montanari, 1991).

The Caravaca sequence is one of those in which the Ir anomalies were originally described (Smit & Hertogen, 1980). Its lithology is marly, the K/T limit being clearly marked by a lamina of clayey sediment (3-5 mm) in which abundant spherules are found, as well as high concentrations of V, Cr, Fe, Ni, Zn, or As, among other elements (Smit & Hertogen, 1980; Martínez Ruíz *et al.*, 1991).

Although these spherules have been widely studied, there are still contrasting opinions regarding their nature and origin. Smit and Klaver (1981) interpreted them as being directly derived from a projectile rich in chalcofiles and moderately volatile elements, and, therefore, as having been formed at high temperature. Hansen *et al.* (1986) considered that these spherules are the results of the diagenetic infill of Prasinophyte algae, and Montanari *et al.* (1983) interpreted them as diagenetically altered microcrystalline spherules of basaltic composition produced by the impact of a large asteroid in an ocean basin.

Methods

The spherules examined by us were separated by handpicking using a stereoscopic microscope. Their mineralogical, morphological and chemical characterization was carried out by XRD (Philips PW 1710, Department of Mineralogy and Petrology, University of Granada), SEM (Zeiss DSM 950) and EPMA (Cameca Camebax SX-50) (Technical Services, University of Granada), and with a Cambridge S-360 SEM unit equipped with Link AN 10000 microanalysis (University of Bari).

Results and Discussion

The morphology of the spherules is generally globulose (Fig. 1A) and, less frequently, dropshaped. Their size ranges from 100 to 1000 μm. Their composition is that of practically pure K-feldspars: $Si_{3,03}\ O_8Al_{1,03}\ K_{0,93}Na_{0,01}$. They present dendritic, spherulitic and fibrous-radial internal textures (fig. 1B), typical of the rapid crystallization of silicate liquids, which led Smit & Klaver (1981) to consider them as products formed at high temperature. However, according to Epstein (1982), the $\delta^{18}O$ value (27‰) indicates a low temperature origin. Our XRD data (low temperature sanidine), together with the scarce Na content, are also consistent with the latter hypothesis.

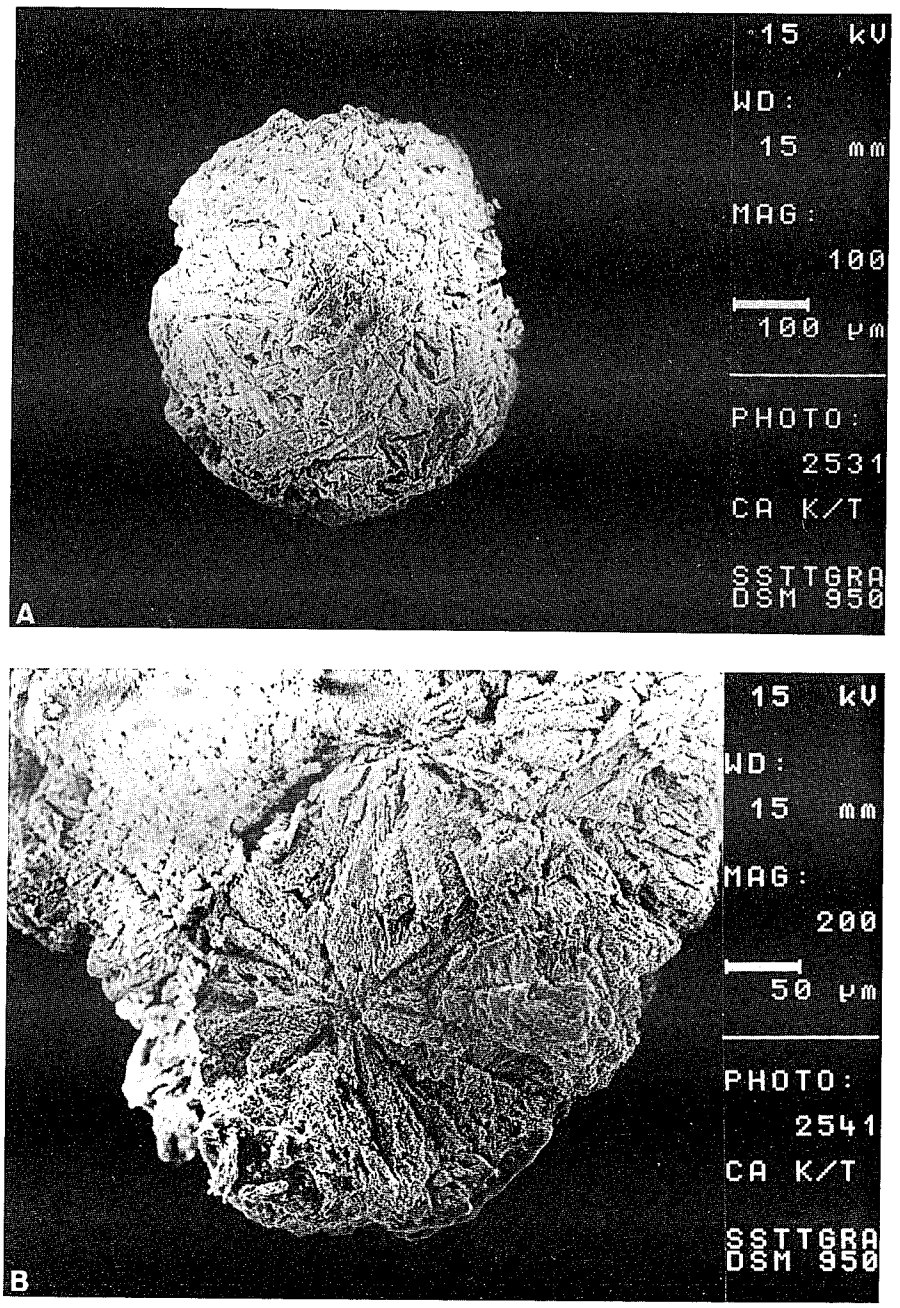

Fig. 1.—SEM photographs of Kfs spherules showing globulose morphology (A) an fibroradial internal texture (B)

Since the textures described above suggest rapid crystallization, the K-feldspar must have replaced some other mineral formed under these conditions. In fact, the replacement of primary plagioclase by K-feldspar is common in gabbros and anorthosites (Duffin, 1989), and these textures can be found in primary feldspars, pyroxenes and rapid crystallizing olivines (Bryan, 1972; John & Glass, 1974; Montanari, 1991). Thus, Montanari (op.cit.) considers that the spherules, formed by an impact against oceanic crust, were originally of basaltic composition and crystallized in the impact cloud to Ca-plagioclase, pyroxene and olivine.

Until now there was no evidence as to the possible precursor mineral of the spherules found in the Caravaca sequence. Our SEM and EPMA analyses have revealed that some spherules have nuclei, which could correspond to the precursor mineral, and whose composition is similar to a mafic type (SiO_2 = 56 %; Al_2O_3 = 10 %; MgO = 8.5%; FeO = 13%; CaO = 3%; Na_2O = 2%; K_2O = 0.9%). Our opinion is that the original mineral was probably a pyroxene, later altered to an amphibole, although its present state of preservation does not permit the calculation of its exact formula. This hypothesis is supported by the existence of spherules of clinopyroxene in other sequences, specifically Hole 577 DSDP on Shatsky Rise in the West Pacific (Smit, 1990).

Clinopyroxenes have been described with dendritic textures in glass spherules associated with the North American microtektites (John & Glass, 1974), which suggests that the spherules could have been produced by the impact of a large extraterrestrial body. However, these textures do not exclude a volcanic origin, as they have also been described in glass spherules formed by both volcanic processes and by shock melting (Lofgren, 1971). Although the real effects of volcanic activity of the size and intensity proposed for the end of the Cretaceous are unknown, and so this hypothesis cannot be discarded, the lack of association of these spherules with clearly volcanic products strengthens the case of the extraterrestrial hypothesis.

Conclusions

The spherical shapes and quench-textures indicate that these spherules formed as liquid silicate droplets. The XRD data, together with the chemical purity of the Kfs, indicate a low temperature of origin for this mineral, which means that it must have pseudomorphically replaced another precursor mineral during diagenesis of the sediment. The parent material of the spherules was probably of mafic composition, since this is the composition of the relicts found in their interior. The original mineral was probably a pyroxene, although it has been altered to an amphibole-type composition.

Acknowledgments

Financial assistance was provided by Research Group 4065, Spanish-Italian Joint Action 9/1992, and Projects (DGICYT) PB-87-022801 and PB-870271.

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Recibido el 30 de enero de 1992
Aceptado el 21 de febrero de 1992