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Age and Crustal Structure of the Canary Islands

A Discussion

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Abstract. The postulation of a Mesozoic age for the shield-building basaltic series of Gran Canaria and Tenerife by Storevedt et al. (1978), based upon paleomagnetic data from these islands, is inconsistent with abundant and concordant K/Ar-ages from several laboratories. These latter data leave no doubt that no rocks older than Mid-Miocene have been found on Gran Canaria and Tenerife. Moreover, no volcaniclastic layers older than Miocene were found in Deep Sea Drilling cores near the Canary Islands. Also, the volcanic apron around at least Gran Canaria appears to be Miocene in age judging from seismic reflectors that extend to well-dated drilled sections. There is no evidence for a sialic crustal layer extending beneath all or any of the Canary Islands.

Key words: Canary Islands – Crustal structure – Volcanic Islands – Potassium Argon Ages – Paleomagnetism.

1. Introduction

Storetvedt et al. (1978) have used paleomagnetic data from Gran Canaria and Tenerife to postulate that the Canary Islands were built up during two major volcanic pulses, the first occurring in the Mesozoic (Late Cretaceous or earlier) and the second during Late Tertiary. They also propose that their data, combined with other lines of evidence, favor 'a continental origin of a crustal belt (including the Canary Islands) extending seaward into water depths of at least 4,500 m'.

Storetvedt et al. (1978) appear to have overinterpreted their data and those from the literature, and several relevant papers were not discussed:

A variety of geophysical and geological studies (see below) have been carried out in this part of the Atlantic (off the northwest coast of Africa) during the last fifteen years, this being a key target area in studying the evolution of passive continental margins. The conclusions of Storetvedt et al. (1978) will, therefore, be discussed in detail, using published and some unpublished material.

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2. Age of the Canary Islands

K/Ar-age determinations on rocks from the Canary Islands were published by Rona and Nalwalk (1970), Abdel-Monem et al. (1971; 1972), Lietz and Schmincke (1975), Grunau et al. (1975), Stillman et al. (1975) and McDougall and Schmincke (1976) and a general discussion of these data was given in Schmincke (1976). More than 80 K/Ar-age determinations are available for Gran Canaria alone, making this one of the most thoroughly dated oceanic islands. The age determinations by Abdel-Monem et al. (1971; 1972) are confirmed in a general way by the later workers. The oldest lavas on Gran Canaria, the shield-building alkali basalts, totalling 1,000 m exposed above sea level, were erupted about 13.5–13.7 M.a. ago (McDougall and Schmincke, 1976).

In striking contrast, Storetvedt et al. (1978) concluded from their paleomagnetic measurements on oriented hand specimens that the pole positions for these lavas are similar to *Mesozoic* pole positions in Africa and that the *minimum* age of this series is, therefore, upper Cretaceous and 'it may well have covered a broad time span within the Mesozoic' (loc. cit. p. 328). With the Mesozoic spanning from ca. 65–230 M.a. and the Late Cretaceous from about 65–100 M.a., the difference in age determined by the authors cited and Storetvedt et al. (1978) amounts to some 50 to 200 M.a.

(a) Are the Published K/Ar-Determinations on Rocks From Gran Canaria Reliable?

Storetvedt et al. (1978), in noting the discrepancy, suggested that incomplete retention of radiogenic argon in the older lavas, possibly caused by 'extensive mineral alteration in the rocks and by extensive magmatic activity in late Tertiary times' (p. 329) makes the published K/Ar-age determinations of dubious value. In support of their opinion they quote age discrepancies between the data by Abdel-Monem et al. (1971; 1972) and stratigraphic data of other authors. Indeed, it was the *relatively* large spread of several million years for the shield lavas on Gran Canaria that resulted in the detailed study of McDougall and Schmincke (1976), initiated because geologic evidence suggested rapid build-up of these shields (i.e., within <1 M.a.) as on other oceanic volcanic islands. Their prediction was confirmed by 20 K/Ar-determinations lying between 13.1 and 13.9 M.a. contrasting with 5 determinations between 10.2 and 16.1 M.a. by Abdel-Monem et al. (1971) for only the upper part of the series. Differences in sampling and/or analytical methods may explain this descrepancy, much emphasis being placed in the study of McDougall and Schmincke (1976) to collect and date only fresh rocks. I suspect (Schmincke, 1976) that careful and detailed study of the shield lavas of other Canary islands will reveal similar differences with the *relatively* large spread in the reconnaissance study of Abdel-Monem et al. (1971; 1972) being reduced to 1 M.a. or less. While such differences, which are common in similar studies of other islands, are relevant for problems of magmatic evolution, they are rather unimportant for the question posed by Storetvedt et al. (1978). I have no doubt that more detailed study will confirm the Miocene (eastern and central Canaries) or Pliocene (western Canaries) age of the shields. For Gran Canaria, agreement between the studies of Abdel-Monem et al. (1971), Lietz and Schmincke (1975) and McDougall and Schmincke (1976) is excellent for rocks younger than 10 M.a.

(b) Are the Rocks of the Shield-Building Series of Gran Canaria Unsuitable for K/Ar-age Determinations?

There are indeed altered basalts within the shield series – but highly altered rocks can also be found on the top of Recent Pico de Teide and alteration may not, therefore, be related to age. Thin section examination of a number of shield lavas dated by Abdel-Monem et al. (1971) shows some to be somewhat altered, however, the vast majority of the shield-building basalts are rather fresh with regard to K-bearing phases (generally feldspar). Suitable specimens can be found if sampling is done carefully.

Red soils (Storetvedt et al., p. 318) on Gran Canaria have developed (during the Pliocene?) on the northern side of the island, chiefly in Pliocene/Quaternary basaltic pyroclastics. Red horizons are rare in the shield basalts, and close examination shows that most, if not all, existing red layers result from baking by overlying lavas. The further suggestion that later magmatic activity (phases II and III, Schmincke, 1976) has caused radiogenic argon to have leaked from the rocks is, again, unsupported by facts. Examination of the extremely well exposed, up to 1,000 m thick, shield series shows that samples studied by Abdel-Monem et al. (1971, 1972) and McDougall and Schmincke (1976) on Gran Canaria are mostly from areas many kilometers away from any later intrusions. These rocks have generally not been heated appreciably since their solidification, the alteration being of low temperature origin which is common in rocks of this age but is not detrimental for age determinations when only fresh portions are selected. The high degree of consistency within and between laboratories, the agreement between the stratigraphic sequence and the age determinations, and between rock and mineral ages indicate that construction of the *subaerial* part of the shield stage of Gran Canaria took place chiefly between 13 and 14 M.a. B.P.

(c) Biostratigraphic Evidence

During Leg 47A, 'Glomar Challenger' drilled and continuously cored a hole (site 397) about 100 km SE of Gran Canaria penetrating 1,453 m of sediment with a 1,300 m thick section of Quaternary to earliest Miocene (20 M.a.) directly overlying lower Cretaceous sediments. The oldest volcaniclastic debris flow deposits are about 17 m.y. old, based on biostratigraphic evidence, while abundant silicic air fall tephra layers occur throughout the younger sediments (Schmincke and v. Rad, 1979). The only exception is a 19-M.a.-old ash layer. No pyroclastic rocks were found in early Miocene, Paleogene or Cretaceous sediments penetrated at the adjacent slope DSDP Dite 369 (Lancelot et al., 1977) nor in the earliest Miocene or Early Cretaceous of Site 397.

The chemical composition of Miocene glass shards found at Site 397 matches very well that of the Miocene rhyolites of Gran Canaria of the same age, this being a rock group of unique composition in the Canaries. This evidence indicates that the main subaerial volcanic phase of the Canary Islands commenced during the early to middle Miocene. Moreover, Schmincke and v. Rad (1979) have interpreted different types of pyroclastic rocks from Site 397 as representing the submarine, subaerial shield and subaerial post-erosional stages of the island volcanoes.

Age of the Canary Islands (Summary). All available data indicate that Gran Canaria did not rise above sea level before mid-Miocene. The submarine part of the island may not be *appreciably* older because Miocene seismic reflectors traced from Glomar Challenger sites clearly interfinger with the volcanic apron around Gran Canaria (Wissmann, personal communication 1979).

The only published K/Ar-age determinations of Canary Island rocks older than Miocene are two Oligocene ages on plutonic and metamorphic rocks from Fuerteventura (Abdel-Monem et al., 1971); rocks from the same complex were dated as Miocene by Grunau et al. (1975). The intrusions must obviously be younger than the Late Cretaceous sedimentary rocks which they intrude. These rocks are from the Betancuria massif which also contains folded and uplifted upper Cretaceous marine sedimentary rocks and is clearly the most complex area in the Canary Islands (Stillman et al. (1975). According to Robertson and Stillman (1979) the oldest volcanic rocks on Fuerteventura are of submarine origin and were deposited on Albian calcareous pelagic sedimentary rocks, after an hiatus of unknown duration, in Late Cretaceous or early Tertiary time. The top part of the sequence, however, is interbedded with Late Oligocene to early Miocene shallow water sedimentary rocks that predate intrusion of a major dike swarm and later igneous events. Canary Island volcanoes do not appear to have risen above sea level before mid-Miocene. Submarine activity may have started earlier (Eocene?) based on still inconclusive seismic evidence (Uchupi, et al., 1976; Grunau et al., 1975; Watkins et al., in press). A 'mid-Tertiary' age of the Canary Island volcanism is also indicated by the obvious disruption of the Tertiary continental rise prism into a thick western segment (west of the Canaries) and eastern part between Cape Bojador and the Canaries (Uchupi et al., 1976, p. 846, Fig. 26).

Paleomagnetic Data. Storetvedt et al. (1978) base their conclusion on paleomagnetic data from Gran Canaria and Tenerife and the reconstructed pole positions for the shield series which they conclude indicates upper Cretaceous or older Mesozoic age. As a petrologist I am unable to fully judge their evidence but it must be emphasized that Watkins (1973) concluded that *his* pole positions were quite compatible with the Late Tertiary ages. It would have been valuable to compare data from the more detailed treatment by thermal and alternating field demagnetisation by Storetvedt et al. (1978) with those by Watkins (1973) using samples from the same sites. Storetvedt et al. (1978), who give no sampling localities, state that 'it is not known to which extent these sampling localities may duplicate those of earlier studies' (op. cit. p. 319). Earlier authors did give detailed localities, however, and McDougall and I were able to resample all localities of Abdel-Monem et al. (1971) of interest to us, using published descriptions and still visible drill holes. Watkins, now deceased, unfortunately cannot defend himself, which, no doubt, he would have done with vigor.

3. Nature of the Crust Beneath and Around the Canary Islands

Storetvedt et al. (1978) have combined their speculations on a Mesozoic age for the islands of Gran Canaria and Tenerife with unrelated and, in part unsupported, highly speculative or questionable data to extend their idea to all of the Canary Islands and to the regional crustal structure.

(a) Basement Complexes

Storetvedt et al. (1978) restate the hypothesis of Fuster et al. (1970) that a layered basement complex underlies all of the Canaries and is exposed in some. However, there is little foundation for this theory (Schmincke, 1976). The two large central islands, Tenerife and Gran Canaria, have no such basal complexes exposed. The complex on La Palma is about 2–3-m.y.-old judging from microfossils found in inter-pillow sediments (Berggren, personal communication to H. Staudigel, 1978). The layered basement complex on Fuerteventura is Miocene or, in part, older, while that of La Gomera has not been dated. A much more likely explanation is that these complexes are part of the substructure of an island, being a plexus of submarine volcanics, intrusives and sediments that probably make up much of the submarine part of most oceanic volcanic islands (Schmincke, 1976; Schmincke and Staudigel, 1976).

(b) Sialic Substratum Under the Canaries?

The (rather old) question as to whether the Canary Islands are underlain by continental or oceanic crust has been discussed elsewhere in detail (Schmincke, 1976). Schmincke (1967) suggested that Gran Canaria and probably the Western Canaries were volcanic islands built on oceanic crust and not part of a tectonically broken up, sialic microcontinent. Utilizing geological (Rothe and Schmincke, 1968) and marine geophysical data (Dash and Bosshard, 1968), a 'subdivision' was made between the Eastern Canaries, possibly or probably underlain by continental crust, and an oceanic central and western area. Dietz and Sproll (1970) built on this hypothesis and postulated, based on *their* computer fit on Africa and North America, that the Eastern Canaries block is probably a microcontinent or sialic continental fragment detached from the African margin. Rona and Nalwalk (1970), in reporting some K/Ar-age determinations from Fuerteventura, simply restated views of the earlier authors and concluded 'We *speculate* that the igneous activity was related to possible rifting of the Eastern Islands from Africa' (pp. 2118–2119, italics mine). Storetvedt et al. (1978, p. 318) on the other hand, stating that Rona and Nalwalk (1970) and Dietz and Sproll (1970) had given '*evidence* for a sialic substratum under the Canaries' (italics mine), omit the major distinction of most authors since 1967 between Eastern and Western Canaries. In three papers by Shell geologists (Beck and Lehner, 1974; Grunau et al., 1975; Lehner and De Ruiter, 1977) (neither mentioned by Storetvedt et al., 1978), apparently using much unpublished information, cross-sections of the area between the Eastern Canaries and Africa are presented. Interestingly, the first published section shows continental crust extending from Africa to the Eastern Canaries (Beck and Lehner, 1974, Fig. 12) while in subsequent, more detailed accounts of the crustal structure in the vicinity of the Canaries, this continental crust has been replaced by a question mark (Grunau et al., 1975; Fig. 5; Lehner and De Ruiter, 1977, Fig. 3). The Concepcion Bank part of the Canary Ridge is interpreted as a tectonic unit of volcanic origin based on refraction seismic investigations (Weigel et al., 1978). The boundary between oceanic and continental crust could even lie near the present Moroccan slope, if recent seismic data, showing a 5.8 km/s layer at 8.5 km depth within (Wissmann et al., 1977) the sedimentary basin between the Eastern Canary Island – Concepcion Bank complex and the shelf of Morocco are interpreted as representing Jurassic deep water carbonate or even oceanic layer 2, as also suggested by the 6 km/s velocity given in Fig. 5 of Grunau et al. (1975) (Weigel et al., 1978).

(c) Erosional Unconformities in the Shield Volcanics on Gran Canaria

Storetvedt et al. (1978) quote Fuster et al. (1968) for the existence of erosional unconformities between the 'various petrographically different units of the older series' on Gran Canaria (p. 318). They have used this evidence to state 'Recalling the existence of erosional discordances within the older lava sequence of Gran Canaria there are in fact reasons to suggest that rifting and lava extrusion may have taken place intermittently (within a subsiding continental belt between Africa and North America) over a time span covering *at least a greater part of the Mesozoic*' (italics mine). Actually, the only major erosional unconformity proposed by Fuster et al. (1968) does not exist. Fuster et al. (1968) opposed the view of Schmincke (1967) that extrusion of a thick series of rhyolite lavas and ignimbrites followed immediately after the shield-building basalts, that this series was associated with caldera collapse, and that there followed intrusion of a large trachytic cone sheet swarm. This group of investigators (Hernán Reguera, 1976) has now accepted both caldera collapse and cone sheet swarm and abandoned the idea of a large erosional unconformity (Hernán Reguera, 1976). McDougall and Schmincke (1976) have documented in detail that there are no significant age differences between the older basalts and the overlying rhyolites, nor is there a significant age difference above or below the only major erosional unconformity found *within* the shield basalt series (i.e., magmatic phase I of Schmincke, 1976, or the 'older lavas' of Storetvedt et al., 1978), this having been described by Schmincke, 1968, but not by Fuster et al., 1968. Moreover, erosional unconformities such as the latter and that between magmatic phase I and the Pliocene magmatic phase 2 on Gran Canaria are commonplace on all volcanic islands.

4. Conclusions

The better known elements of the evolution of the Canary Islands are, judging from presently available data from marine geophysics, deep sea drilling and geological studies of the islands: appearance of volcanic islands – and possibly initiation of melting anomalies in the mantle – during early Miocene, initially in the Eastern Canaries, followed by Gran Canaria (which is rather precisely data) and later the Western Canaries. This migration corresponds approximately with known sea floor spreading rates. Exceptions to this pattern *may be* the basal complexes of Fuerteventura and Gomera but data are still sparse and contradictory. The location of the boundary between the oceanic and continental crust is still unknown but evidence is mounting that it is at least as far east as the Eastern Canaries and is possibly still further east. What initiated the melting anomaly under the Canaries is unknown. Important structural elements in the evolution of the archipelago include vertical movements in some islands with thousands of meters of throw. These are major, tectonic events ranging in age from early Tertiary (?) in Fuerteventura to Pliocene/Quaternary on La Palma, suggesting that the stress field responsible for these movements may still be operative. Other islands like Gran Canaria were remarkably stable with respect to sea level, indicated by the similarity in evelation of Mid-Miocene valley bottoms of these islands to those of today. Regressions and transgressions at the Miocene/Pliocene boundary are an exception. Most islands experienced several major magmatic phases, similar to those known from Hawaii, with a voluminous shield phase of moderately alkalic basalts followed after major erosional intervals by much smaller volumes of more alkalic undersaturated magmas.

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