Trabajos de Geología, Universidad de Oviedo, 29 : 440-444 (2009)

Oviedo (Spain) 1-3 July 2008 International Meeting of Young Researchers in Structural Geology and Tectonics
ORSGET

Dome formation mechanisms in the southwestern Central Zone of the Damara Orogen, Namibia

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Abstract: Mapping of the Palmenhorst and Ida Domes in the Central Zone of the Damara Orogen, Namibia, shows that Pan-African domal structures cored by Palaeoproterozoic basement gneiss have been formed by Type 2 fold interference between SSE-verging, recumbent folds and NE-trending, upright folds. Granite relationships indicate that the earlier SSE-verging event occurred at 520 Ma.

Keywords: Damara Orogen, basement-cored domes, dome formation, interference folding, collision tectonics, Pan-African.

The Central Zone (CZ) of the Damara Orogen, Namibia, is a well-exposed high-temperature-low-pressure Pan-African metamorphic belt, formed during the collision between the Congo and Kalahari Cratons between ~500 and 600 Ma (Miller, 1983; Prave, 1996). Within the CZ, NE-trending elongate dome structures ranging in size up to 20 km length and 5 km width occur, which may be cored by Palaeoproterozoic basement gneisses of the Abbabis Basement Complex (Smith, 1965; Kröner *et al.*, 1991), and which have been attributed to a number of formation mechanisms, including interference folding by both multiple and single deformation phases (Smith, 1965; Oliver, 1994), diapiric rise of mobilized basement into the cover (Barnes, 1981), deformation by intruding granite plutons (Coward, 1981; Kröner, 1984), mega-scale sheath folding (Coward, 1983), metamorphic core complex development (Oliver 1994, 1995), and single phase constrictional deformation (Poli, 1997). This study aims to examine dome formation mechanisms in the CZ using evidence from the Khan-Palmenhorst and Ida Domes in the southwestern part of the CZ (Fig. 1).

Results

Ida Dome

In the Ida Dome, mapping reveals that this structure is a slightly non cylindrical km-scale fold with a moderately NE-plunging fold axis, and a curved axial trace. The structure is overturned to the SE, and a transect across the dome along the Swakop River (towards the southern end of the dome) records a large number of NE-plunging fold hinges, parallel to a consistent NE-plunging mineral stretching lineation (Fig. 2).

Additionally, this mapping (Fig. 3) shows that the lithological distribution of rocks in the Ida Dome is far simpler than the distribution shown on previous maps (1:250 000 Geological Survey map; Barnes, 1981) The stratigraphy along the eastern edge of the dome is a typical Damaran sequence (i.e. from a core of Abbabis Basement Complex moving upwards towards the east through Ketosis Fm, Khan Fm, Rossing Fm and Chuos Fm – see figure 1), and there is no need to invoke earlier deformation phases (Barnes, 1981) or thrusting to explain missing stratigraphy (as implied on the 1:250 000 map). The Ida Dome represents a km-scale fold formed by a single deformation phase, which postdates an early S-verging, recumbent folding event preserved in the Khan-Palmenhorst Dome (see below). Petrography of metapelites from the Ida Dome indicates that peak upper amphibolite facies metamorphism (~700 °C, Nex *et al.*, 2001) was reached towards the end of this folding event. No microstructural evidence is preserved in the Ida Dome recording earlier deformation events found in the Khan-Palmenhorst Dome (see

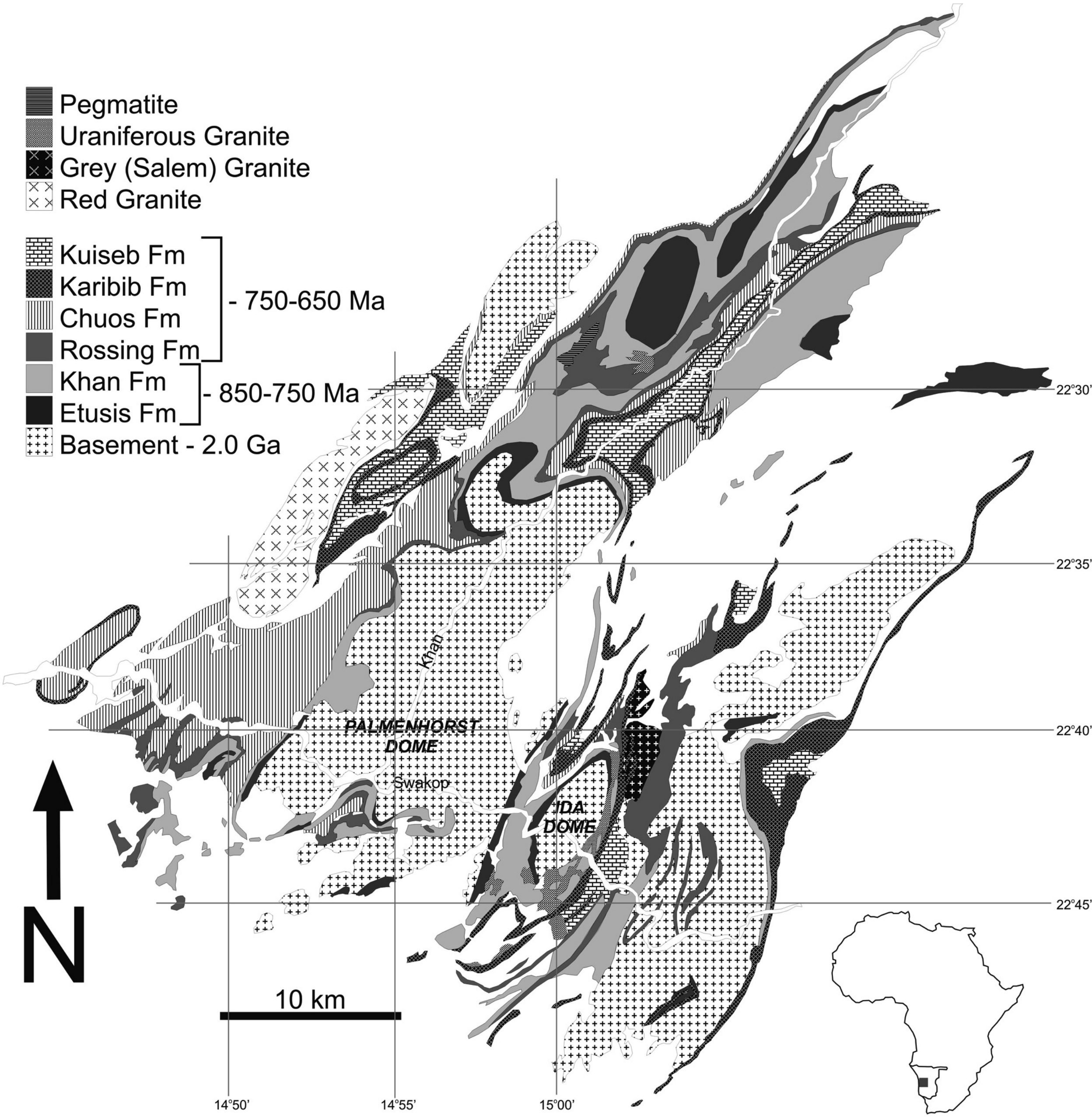

Figure 1. Geological map and stratigraphic sequence of the CZ showing the location of the Khan-Palmenhorst and Ida Domes, as well as other dome structures in the CZ (after 1:250 000 geological series sheet 2214 Walvis Bay, Geological Survey of Namibia, 1995). Note the large area of basement shown in the Khan-Palmenhorst area. Approximate location of the study area within Namibia is also shown.

below). Within the Ida dome, a variety of granites are found, and these make up a significant volume (30-50%) of the outcrop in the area. Types include grey "Salem type" granites (Smith, 1965), uraniferous leucogranite sheets, and "C-type" leucogranites (Nex, 1997), and these granites occur as sheets or small (tens to hundreds of metres) bodies, which do not deform their host rocks, indicating passive emplacement. Despite the significant volumes of granite, there are no km-scale "plutons" in the area, and the granite is not concentrated near the core of the Ida Dome.

Khan-Palmenhorst Dome

An analysis of lithological distribution shown on the 1:250 000 geological map of Namibia reveals apparent fold interference patterns within and adjacent to the Khan-Palmenhorst Dome (Fig. 4). Additionally,

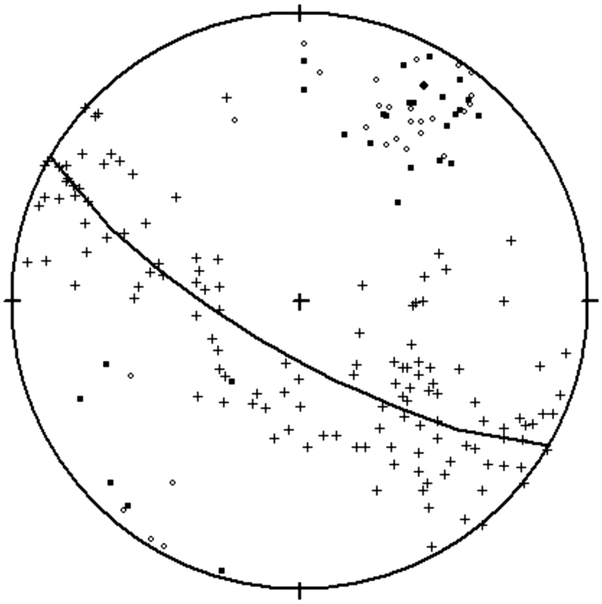

Figure 2. Equal area lower hemisphere stereographic projection of structural data from the Ida Dome. Black squares: fold hinges; plus signs: poles to lithological layering; open circles: mineral stretching lineations.

mapping carried out during April and May 2007 has revealed the presence of recumbent F1 structures refolded by F2 within the Khan-Palmenhorst Dome (Fig. 4), a previously mapped area (Smith, 1965; Jacob, 1974) as consisting entirely of Abbabis Basement Complex (Fig. 1). These S-verging recumbent folds structures have been refolded by upright to steeply NW-dipping, gentle to moderate NE-trending folds, resulting in the Type 2 fold interference pattern (Ramsay, 1967) (Fig. 4).

Evidence for fold interference is found in the Hildenhof area, near the south of the Khan-Palmenhorst Dome. Here, tight m- to dm-scale folds with moderately SSE-dipping axial planes and sub-horizontal, ENE-SSW-trending fold hinges (Fig. 5) have fold vergences which define larger scale (hundreds of meters) folds which may represent parasitic folds on a ten of km-scale anticlinal D1 structure. These folds are refolded (on both a m- and km-scale) by close, upright, NE-trending folds. This interference is evident on an outcrop scale as well as in the map patterns (Fig. 4). Within the Hildenhof area, grey "Salem-type" granites (Smith, 1965) intrude during this D1 folding event, and constrain the timing of this event to ~520 Ma (Longridge, unpublished data). They are intruded axial planar to m- and dm-scale D1 folds, and are also folded by these folds, and

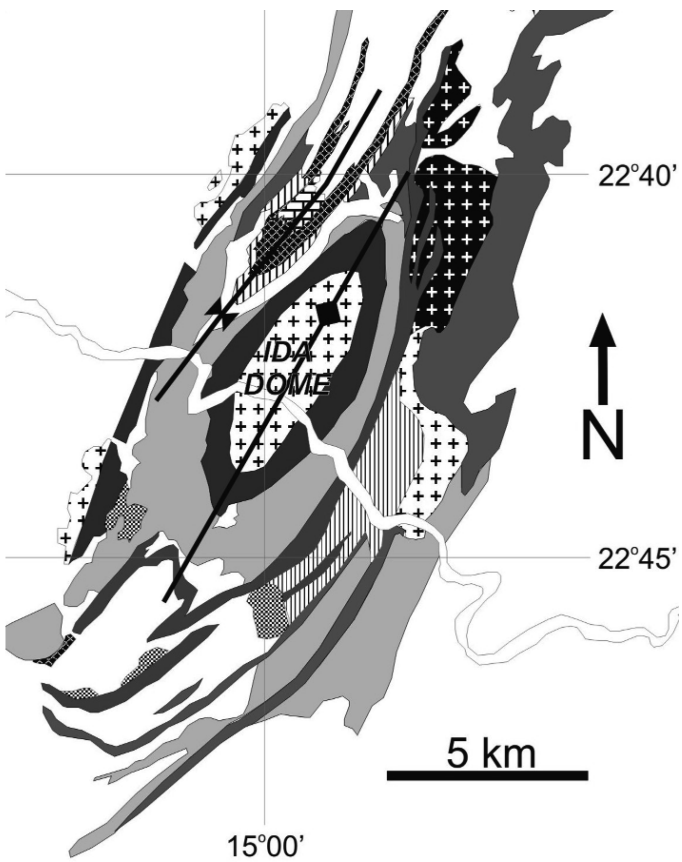

Figure 3. Geological map of the Ida Dome, showing greater distribution of Damaran Sequence rocks, and less Abbabis Basement Complex in the centre of the dome compared with Smith (1965), as well as a typical Damaran stratigraphic sequence on the eastern edge of the dome. The domal shape apparent on the map is due to non-cylindricity of the F2 anticline rather than a fold interference structure.

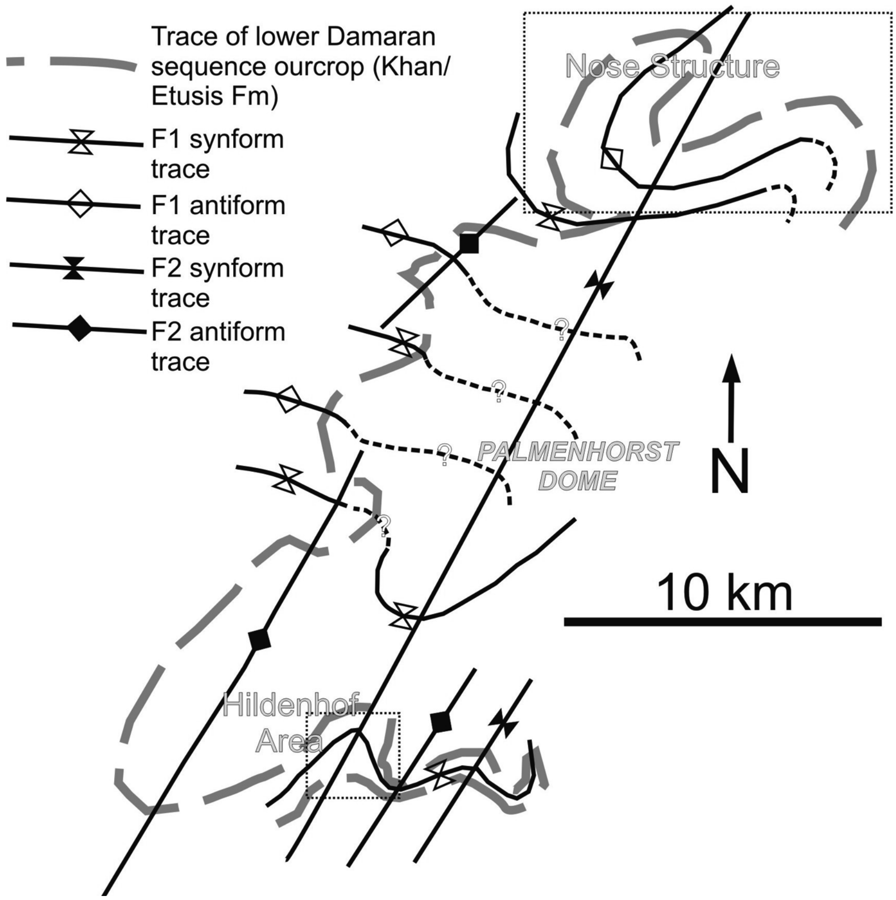

Figure 4. Fold interference patterns in the Khan-Palmenhorst Area, as inferred from mapped distribution patterns (1:250 000 geological map) and from mapping carried out as part of this study. The locations of the Hildenhof Area and Nose Structure are also shown. Dashed lines indicate uncertainty regarding possible continuation of fold traces into Abbabis Basement Complex rocks in the core of the dome.

preserve a moderate fabric axial planar to these folds (Fig. 5). Late uraniferous leucogranite sheets cut both D1 and D2 folds. Peak metamorphism postdates development of these structures, and D1 microstructures are not preserved due to recrystallization during this thermal event.

Discussion

In both the Ida Dome and the Khan-Palmenhorst Dome, granites are emplaced passively as sheets and small bodies, and are not constrained to the cores of domes. Dome formation, due to deformation by intruding plutons, should produce plutons which deform their host rocks, neither of which are found, and this model can thus be discounted. No radially distributed linear structures are found around the Ida Dome, a feature which would be expected should the formation mechanism be due to diapiric rise of mobilised basement, which also appears unlikely. No km-scale extensional detachments are found in the area at the basement-cover interface, which precludes an extensional core-complex model of formation.

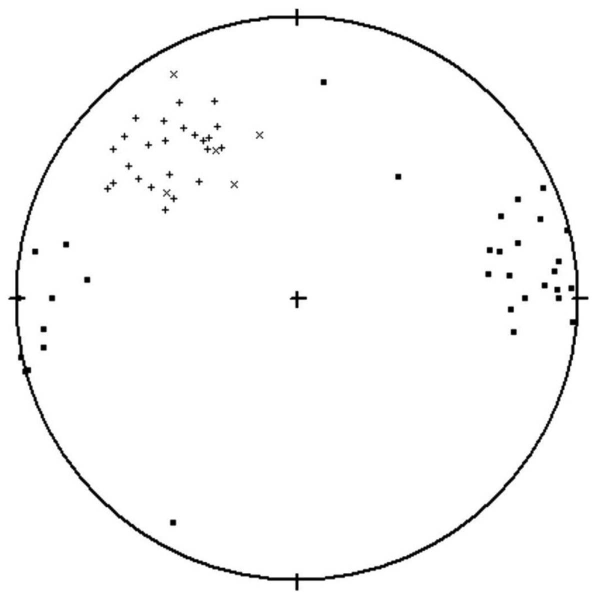

Figure 5. Equal area lower hemisphere stereographic projection of representative structural data from the Hildenhof area. Black squares: fold hinges; plus signs: poles to lithological layering; crosses: poles to foliations in grey granite. Note the ENE-WSW-trending D1 fold hinges, with fewer NE-SW D2 fold hinges.

In order for the Ida structure to be a "dome", *sensu stricto,* it should be moderately doubly-plunging to both the NE and the SW. However, since structures plunge NE and there is no evidence for moderately SW-plunging structures, it is in reality a NE-plunging non cylindrical km-scale fold rather than a true dome.

In the Khan-Palmenhorst dome, there is far less Abbabis Basement Complex than represented on the 1:250 000 map. Rather, this area contains a number of km-scale recumbent folds (F1) of Damara Sequence rocks, which have been refolded by upright to steeply NW-dipping NE-trending folds (F2). Such fold interference could explain the patterns such as the "Nose Structure" found at the north end of the Khan-Palmenhorst Dome (Fig. 4), and interpreted by Poli (1997) to have formed by a single constrictional phase of deformation. Km-scale folds such as the Nose Structure are probably parasitic folds on tens of km-scale SSE-verging D1 fold structure.

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