Deep Seismic Sounding in the Area of the Damara Orogen, Namibia, South West Africa

B. Baier[1], H. Berckhemer[1], D. Gajewski[2], R.W. Green[3], Ch. Grimsel[4], C. Prodehl[2], and R. Vees[4]

[1] Institut für Meteorologie und Geophysik, Feldbergstraße 47, 6000 Frankfurt 1, FRG
[2] Geophysikalisches Institut, Hertzstraße 16, 7500 Karlsruhe, FRG
[3] Bernard Price Institute of Geophysical Research, University of Witwatersrand, Johannesburg, South Africa
[4] Institut für Geophysik, A.-Sommerfeld-Straße 1, 3392 Clausthal-Zellerfeld, FRG

Abstract

Deep seismic sounding in Namibia (South West Africa) were carried out in July / August 1975 by a German-Southafrican team. Three profiles were observed to study the crustal structure and the nature of the crust-mantle boundary of the Damara Orogen with regard to its evolution, supplementing extensive geological and petrological investigations.

Profile I (350 km length - 6 shotpoints) in the Central Zone of the Damara Orogen. In the upper crust two velocity inversions are found. The crust-mantle boundary is a transition zone of variable width rising slightly from a depth of 47 km towards the Atlantic coast.

Profile II (225 km length - 2 shotpoints) in the Southern Zone of the Damara Orogen. It shows relatively high velocities in the upper and middle crust. Because of the limited length only poor information is obtained on the crust-mantle boundary.

Profile III (300 km length - 3 shotpoints) was placed, for reference, on the Kalahari Craton which is adjoining the Damara Orogen in the south. In contrast to Profile I no velocity inversions are found in the upper crust. On this profile the Moho appears as a more distinct discontinuity split into an upper level at 47 km and a lower level at 60 km approximately. There is also no indication of a "mountain root". The interpretation is based on composite plane layer models with variable velocities.

1. Introduction

The Damara Orogen in Namibia (South West Africa) forms part of the Late Precambrian Pan-African mobile belt system. The intra-continental branch of the Damara Orogen is bordered to the north by the Congo Craton and to the south by the Kalahari Craton. The extensive stratigraphic, geotectonic, and petrographic investigation of its nature and development has been a major subject of the research program SFB 48 on intra-continental orogens carried out by the University of Göttingen during the past decade (Martin and Porada, 1977). Supplementary to this work and in order to obtain also some structural information from the third dimension, a deep seismic sounding experiment was performed in the summer 1975 by the geophysics institutes of the universities of Clausthal, Frankfurt, Karlsruhe, Stuttgart, in cooperation with the Bernard Price Institute of Geophysical Research (BPI), University of Johannesburg, South Africa.

The major questions hopefully to be answered by these measurements were the following:

- what is the crustal thickness below the orogen and the adjacent craton?
- does there still exist a mountain root below the Damara Orogen?
- are there significant differences in the crustal structure between the orogen and the adjacent stable area?

Intracontinental Fold Belts
Ed. by H. Martin and F.W. Eder

- are there distinct low velocity zones in the central part of the orogen similar to the Alps?
- what is the structure (and possible nature) of the crust-mantle boundary?
- how does the transition take place from the orogen to the craton?
- what was the effect of the opening of the South Atlantic Ocean on the deep structure of the orogen?
- is there evidence for a palaeosubduction zone?

In order to probe the earth by explosion seismic waves down to at least the crust-mantle boundary in a continental shield area a profile length of the order of 300 km is necessary. The separation of recording stations of approximately 5 km along the profile permits a sufficiently reliable correlation of arrivals on adjacent seismograms but restricts the resolution to larger structures. Also the shotpoint separation of 75 to 200 km is a resolution-limiting factor. In order to keep structural variations small along the seismic profiles and therefore to improve the uniqueness of the interpretation of the data, the profiles were oriented parallel to the strike of the orogen; Profile I along its "Central Zone", Profile II in its "Southern Zone" and, for reference, Profile III on the Kalahari Craton. The original idea to interconnect the profiles by arc observation at constant distances could not be realized for financial and logistical reasons.

There exist a number of different methods to invert the observed travel times into velocity-depth distributions:

- plane (horizontal) layer models with constant velocities
- plane inclined layer models with constant velocities
- time term analysis of layers of variable thicknesses
- plane layers with vertically variable velocities
- composite plane layer models with variable velocities
- ray tracing with vertically and laterally variable velocities

Although the results should show the same principle features they may differ in detail considerably. All methods have some inherent limitations and errors. This should be kept in mind in interpreting the results.

In this paper the data inversion is based entirely on the composite plane layer interpretation technique. The method is briefly described in Chapter 4 and was successfully applied before by Prodehl (1979). It has a rather good resolution of velocities with depth but may lead to considerable distortions if lateral velocity variations become significant. An approach with plane inclined layer models for the same data was made by Green (1979). Further attempts toward the interpretation of these data under particular view angles are found in the diploma theses by Abbas (1980), Gajewski (1981), Grimsel (1981).

2. Field experiments

According to the principles mentioned above three reversed profiles were observed (see Fig. 1).

Profile I runs over a length of 350 km along the axis of the Central Zone of the orogen. Its western end, near Rössing, is located in the Namib desert. It traverses a denuded and deeply eroded crust with rocks of medium- to high-grade metamorphism corresponding to a lithostatic pressure of up to 4 kbar, and large volumes of granitoid intrusions with K/Ar biotite cooling ages of 430-490 Ma (see contribution by Haack). The north-eastern end (near Dankbaar) is covered by thin Triassic and Tertiary sediments. In order to obtain sufficient information on lateral variations within the upper and middle crust 3 additional shotpoints were placed between those at Ubib and Dankbaar. Furthermore use was made of 2 large quarry blasts in the Rössing Uranium Mine.