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A surface wave dispersion study of the lithospheric structure of Africa

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A SURFACE WAVE DISPERSION STUDY OF THE LITHOSPHERIC STRUCTURE OF AFRICA

by

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DISSERTATION

Presented to the Faculty of the Graduate School of

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A SURFACE WAVE DISPERSION STUDY OF THE LITHOSPHERIC STRUCTURE OF AFRICA

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ABSTRACT

Lithospheric structure of the African continent is, in general, poorly known; the analysis of surface wave dispersion provides the only remaining opportunity to add to our knowledge of African lithospheric structure using existing data sets. In this study, long-period, vertical-component seismograms were analyzed from WWSSN seismograph stations in the region. Two-station analysis was undertaken for all paths that could provide new information. A new set of computer programs including phase match filtering and inversion were implemented for this study.

The results of this study indicate that the crustal thickness in almost all of Africa is 40 km ± 5 km. Thin (<30) crust is found in the area of the East African rift and an area of thickened crust is found in northern Africa. Areas underlain by a well-developed upper mantle low velocity layer are limited to the East African rift and north Africa. This result would suggest that the lithosphere may be quite thick (>150 km) under much of Africa. Very low phase velocities (and lithospheric shear wave velocities) are found in the East Africa rift area. The high phase velocities associated with the shield areas of southern Africa are not characteristic of the remainder of the continent. The areas of Tertiary uplift and

volcanism in northern Africa seem to correlate with a thickened crust but thinned lithosphere.

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INTRODUCTION

Lithospheric structure studies have become increasingly important in the elucidation of tectonic regimes, but our knowledge of the deep structure of the African continent is very limited. This lack of knowledge is primarily due to the vast area involved, a general paucity of geophysical data, and the small number of seismograph stations in operation. The rift and shield areas of Africa are considered classic, and more knowledge of these features is needed.

An examination of the previous surface wave dispersion work in the African continent suggests that more surface wave studies would be useful. Such studies can provide general information on lithospheric structure at a low cost. The majority of previous geophysical studies have concentrated on small areas of Africa, such as the Gregory rift, the Afar depression and the South African shield, while the remaining stable platform and shield areas have received relatively little attention. Thus, the objective of this study is to determine Rayleigh wave fundamental mode group and phase velocities for a variety of two-station paths crossing the African continent, and to use these data to determine upper mantle and crustal structure along these paths.

A major portion of this study consisted of totally revamping the University of Texas at El Paso geophysics group's surface wave analysis package of computer programs at the University of Texas at El Paso. This was accomplished with the aid of Dr. David Russell of St. Louis University. The major features of this new set of programs were phase-matched filtering and inversion. Seismic surface waves are often composed of overlapping wavetrains representing multipath propagation. A first task in the analysis of such waves is to identify and separate the various components of the wavetrains so that each can be analyzed separately. The separation method which was implemented for this study was phase-matched filtering (Herrin and Goforth, 1977). Application of phase-matched filtering to digital records of Rayleigh waves allowed multiple arrivals to be identified and removed. Phase-matched filter analysis uses the initial estimate of group velocity dispersion determined by using the moving window technique (Landisman et al., 1969) along with the Rayleigh wave spectrum to compute group and phase velocity dispersion curves. These curves and the filtered data provided the necessary inputs to a two-station analysis of dispersion along a particular path of interest.

Having determined the group and phase velocity dispersion curves for the interstation paths, the final step in surface wave analysis was to find a shear wave velocity

model that fitted the surface wave data and, at the same time, was compatible with other geophysical and geological data. An iterative inversion scheme was used to determine a shear velocity model that satisfies both the group and phase velocity data simultaneously. The final step in the analysis was interpretation of the resulting earth models in terms of their tectonic implications. The results obtained were then compared with other regional earth models such as the Canadian shield model (CANSD) of Brune and Dorman (1963), the South American shield results of Renbarger (1984), and the African model (AFRIC) of Gumper and Pomeroy (1970).

GEOLOGIC SETTING

The continent of Africa (Figs. 1 and 2) is characterized by a variety of diverse and significant geological features which include: (1) complex, mineral-rich Precambrian shields; (2) contemporary seismicity and volcanism; (3) Precambrian and Phanerozoic orogenic belts; and (4) the classic East African rift system.

Because of the associated mineral deposits, the Precambrian shield areas have been extensively studied. The Precambrian and phanerozoic geology of the continent is discussed below. The primary sources for this discussion were Clifford and Gass (1970), and Clifford (1974).

Archean Period

The Archean crust of Africa had formed by 3800 Ma. No record of crustal materials is recorded before this time. The Archean period (> 2500 Ma) is recorded only in small areas because most Archean crust has been obscured by younger rocks. Archean areas are composed of high-grade gneisses surrounded by low-grade metamorphosed volcano-sedimentary sequences, the so-called "greenstone belts." A profound change in crustal tectonics, possibly due to changes in convection patterns in the cooling mantle, occurred around 2500 Ma, and the Archean crustal fragments

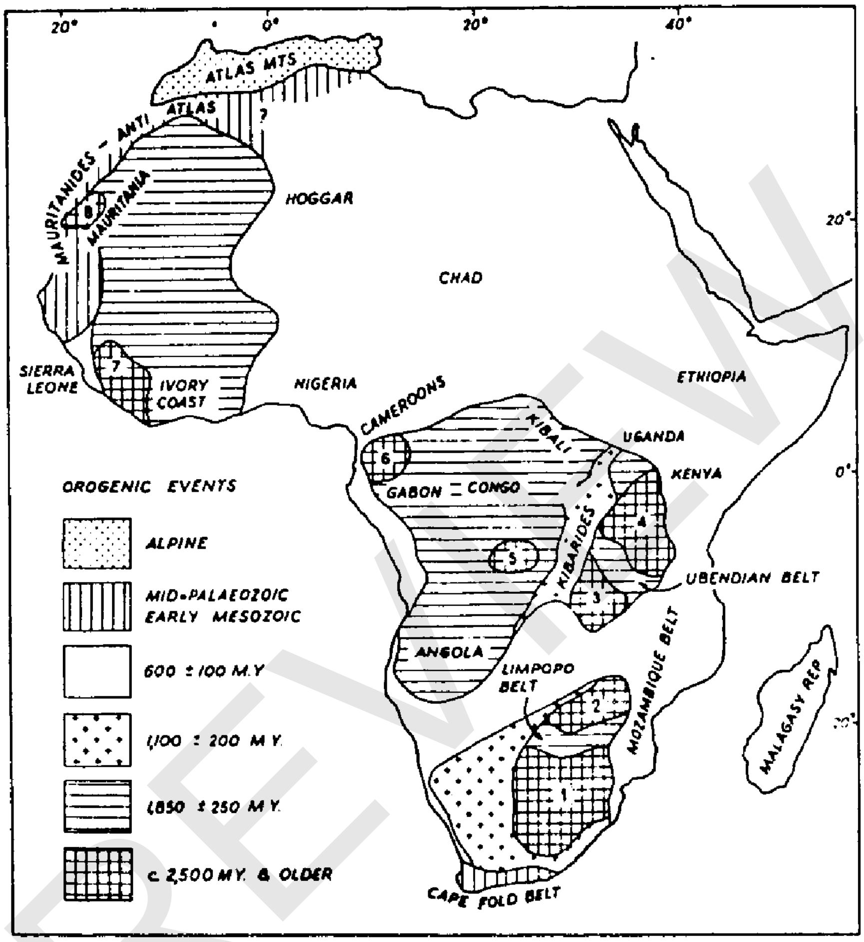

Figure 1. Generalized map of major orogenic structural units of Africa, showing zones in which individual orogenic events are preserved in their "primary" form, undisturbed by subsequent orogeny. Evidence of earliest events, believed to have affected the whole African crust, is now most clearly preserved in remnant "nuclei," numbered as follows: 1, Transvaal; 2, Rhodesia; 3, Zambia; 4, Dodoma-Nyanza; 5, Kasai; 6, Gabon-Cameroons; 7, Sierra Leone-Ivory Coast; 8, Mauritania (from Clifford, 1974).