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A Digital Age Map of the Ocean Floor

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ABSTRACT

We have created a digital age grid of the ocean floor with a grid node interval of 6 arc minutes using a self-consistent set of global isochrons and associated plate reconstruction poles. The age at each grid node was determined by linear interpolation between adjacent isochrons in the direction of spreading. Ages for ocean floor between the oldest identified magnetic anomalies and continental crust were interpolated by estimating the ages of passive continental margin segments from geological data and published plate models.

INTRODUCTION

The age of the ocean floor is an important parameter in the study of plate tectonic processes. An accurate digital age grid is essential for many studies, including plate kinematics, studies of plate driving forces, mantle dynamics, ocean floor roughness and paleoceanography. Several analog maps of the age of the ocean floor have been compiled using magnetic anomaly data [e.g. *Sclater et al.*, 1981; *Larson et al.*, 1985]. A digital version of the latter map was produced by *Cazenave et al.* [1988], at a grid interval of half a degree (approx. 55 km). There are several reasons for the construction of a more detailed age grid. First, the isochrons on Larsen et al.'s [1985] age map are not self-consistent. Therefore isochrons on different plates were constructed independently from each other on conjugate plates, and implies that conjugate isochrons do not reconstruct given any rotation pole. Hence they do not represent isochrons sensu stricto. Second, recent improvements in identifications of magnetic anomalies and plate kinematic models permit a more detailed description of the spreading process. Finally, world-wide sets of geophysical data (such as bathymetry and gravity) are now available at grid intervals of 5 arc-minutes [*NGDC*, 1988, *Sandwell and Smith*, 1992].

OCEAN FLOOR ISOCHRONS

Royer et al. [1992] constructed a global set of isochrons for the ocean basins corresponding to magnetic anomalies 5, 6, 13, 18, 21, 25, 31, 34, M-0, M-4, M-10, M-16, M-21, M-25 and M-29. The geomagnetic time scale of *Cande and Kent* [1992] was used for anomalies younger than chron 34 (83 Ma), the DNAG scale [*Kent and Gradstein*, 1986] for older times. A self-consistent set of isochrons was constructed by Royer et al. [1992] based on a global plate reconstruction model, magnetic anomaly identifications and fracture zones. This was done by plotting a reconstructed map for each isochron time, keeping one plate fixed. These plots included reconstructed magnetic anomaly and fracture zone picks, as well as selected small circles computed from stage rotation poles. Then continuous isochrons were constructed, connected by transforms. The paleo-ridge segments were drawn by finding the best average lines for superimposed magnetic anomaly picks. The positions of paleo-ridge segments were determined by offsets in magnetic lineations and by mapped fracture zones either from seafloor topography or satellite altimetry data. The fracture zone segments were drawn following small circles about stage rotation poles. This procedure, also described in *Müller et al.* [1990], yielded isochrons in the framework of one fixed plate. A complete set of isochrons for all conjugate plate pairs was derived by rotation of every isochron to their present day position. The finite rotation poles that this model is based on are compiled in *Royer et al.* [1992].

PRESENT DAY PLATE BOUNDARIES

Construction of a complete age grid requires knowledge of the present day plate boundary geometry. The boundaries shown on Figure 1 have been compiled based on Geosat exact repeat mission and Geodetic Mission data [*Sandwell and Smith*, 1992], bathymetric data, and earthquake epicenters.

BOUNDARIES BETWEEN OCEANIC AND CONTINENTAL CRUST (COB)

There is a significant area of ocean floor that is older than the oldest mapped isochrons. In order to estimate ages for the oldest ocean floor in ocean basins bounded by passive margins, we assigned ages to continental margin segments based on geological data and published plate models. Because many ocean basins formed by rift propagation, the boundaries between continental and oceanic crust (COB's) of various plates have to be separated into a number of segments with different assigned ages. The references for the COB's in the North and central North Atlantic have been summarized by *Müller and Roest* [1992], and for the South Atlantic by *Nürnberg and Müller* [1992]. References for the Indian ocean and other areas can be found in *Royer et al.* [1992]. South of 60°S a dense grid of Geosat Geodetic Mission data [*Sandwell and Smith*, 1992] has been used to better locate boundaries between continental and oceanic crust in remote areas such as the Antarctic continental margin.

INTERPOLATION OF ISOCHRON AGES

In order to create a smooth grid of ocean floor ages that maintains all sharp age discontinuities at fracture zones, we created a set of densely interpolated isochrons. We assume that the spreading direction between two adjacent isochrons is given by a constant pole of motion, derived from plate kinematic models. We also assume that the spreading velocity between two adjacent isochrons is constant, and that consequently the age varies linearly in the direction of spreading. To simplify the calculations, each pair of adjacent isochrons is transformed to a coordinate system where the pole of motion between the two isochrons is the north pole [*Roest et al.*, 1992]. Then intermediate isochrons were linearly interpolated along plate flow lines. In a stage pole reference frame, this is equivalent to interpolation along east-west parallels. The complete set of isochrons for each stage was subsequently rotated back into the present day framework. This was done for each isochron pair on each plate pair. Fig. 1 shows the result of isochrons interpolated in 1 m.y. intervals for the South Atlantic.

OCEAN FLOOR AGE GRID

To interpolate the ages onto a regular grid, we assume that the isochrons are continuous, which is implemented by densely interpolating between observation points along each isochron. A minimum curvature routine [*Smith and Wessel*, 1990] is used to obtain age values on a regular grid at a resolution of 0.1 degrees, equivalent to 6 arc minutes. Areas of the ocean floor with insufficient data coverage were blanked out in the grid. We included data from selected back arc basins into our grid, where data coverage is sufficient. The resolution of our grid for these areas is typically reduced by a factor of 10 with respect to the oceanic grid, i.e. the resolution in back-arc basins does not exceed 1 degree, and provides merely a rough estimate of the age distribution in these basins.

We used the resulting grid to create a color-coded, shaded map of the ages of the world's oceans. This map is available from the SIO Geological Data Center (see Appendix for details). A reduced black and white version of this map is shown on Figure 2. The digital file with age values of the world's oceans will ultimately be accompanied by several additional data sets, containing, for example, error estimates, local spreading directions and rates, and the paleolatitude at which the crust is inferred to have formed. The digital grid is available at a public ftp site at SIO (see Appendix).

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APPENDIX.

The digital age grid is available at an anonymous ftp site at baltica.ucsd.edu (132.239.121.66). Copies of the map can be obtained from:

Within the USA: The *Geological Data Center, Scripps Institution of Oceanography, 9500 Gilman Drive, La Jolla, CA 92093-0223, USA*, Ph. (619) 534 2752. Price: US$ 40. Methods of payment: Puchase order or check.

Outside the USA: The *Geophysical Data Center, Geological Survey of Canada, 1 Observatory Crescent, Ottawa, Ontario K1A 0Y3, Canada*, Ph. (613) 995 5326. Price: CAN$ 50. Methods of payment: Visa, Mastercard (provide name, on card, number, and expiration date), or international money order. Prices are subject to change.

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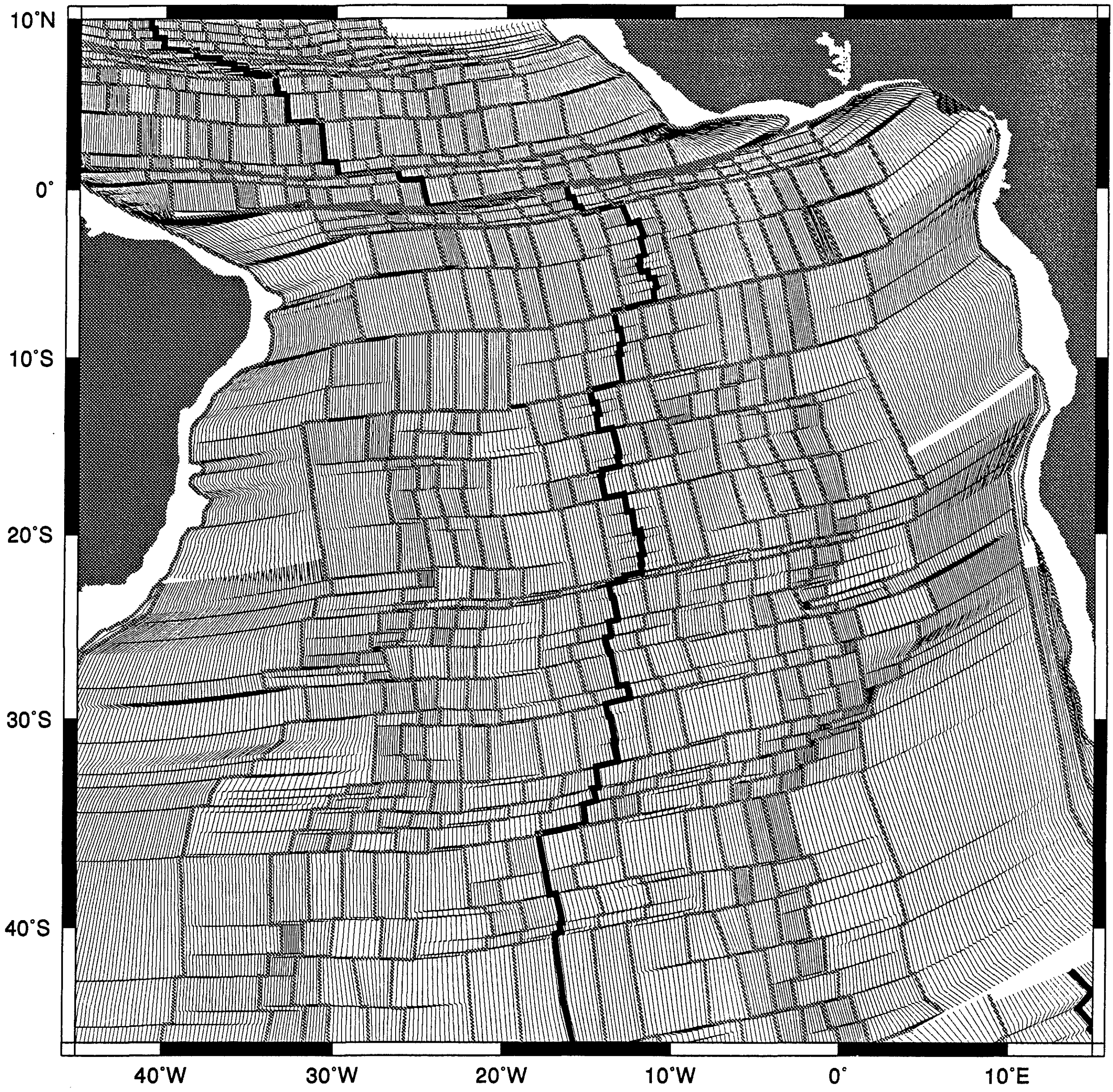

Fig. 1. Seafloor spreading isochrons in the South Atlantic, interpolated in 1 m.y. intervals. Broad grey lines delineate the isochrons bounding the individual interpolated stages. The isochrons correspond to magnetic anomalies 5, 6, 13, 18, 21, 25, 31, 34, M-0, M-4, M-10, M-16, M-21, M-25.

Fig. 2.

A Digital Age Map of the Ocean Floor

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