SPECTRAL ANALYSIS OF HIGH RESOLUTION AEROMAGNETIC DATA FOR THE DETERMINATION OF CURIE POINT DEPTHS IN PARTS OF CHAD BASIN, NIGERIA

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ABSTRACT

The Curie Point Depth (CPD), sedimentary thicknesses and heat flow maps of parts of the Chad Basin, Nigeria were generated through the analysis of radial log power spectral of overlapping square blocks of high resolution aeromagnetic data. This was with a view to evaluating the thermal gradients and associated heat flow beneath the study area.

Nine sheets of High Resolution Aeromagnetic Data (HRAD) of parts of the Nigerian sector of Chad Basin, bounded by Latitudes 11° 30′ to 13° 00′ and Longitudes 12° 00′ to 13° 30′, were acquired from the Nigerian Geological Surveys Agency (NGSA). The HRAD were interpolated onto a uniform grid at 100 m spacing using the minimum curvature gridding method. The regional trend and cultural noise in the data were removed using polynomial surface fitting and upward continuation filtering techniques. The filtered HRAD grid was then subdivided into twenty-five overlapping square blocks with dimensions of 55 km × 55 km. Each block was overlapped by fifty percent with the adjacent blocks. The depth to the centroid (z_0) and depth to the top boundary of the basement (z_t) were calculated from the power spectrum computed for each block and the values of z_0 and z_t were used to determine the CPD. The CPD values and appropriate thermal conductivity were used to estimate the thermal gradients and associated heat flow values. The results were compiled into CPD, sedimentary thicknesses and heat flow maps. 2D forward modelling of profiles taking across the CPD map and the anomalous zones of the Reduced-to-the-Equator map of the filtered HRAD was carried out to obtain five models of the magnetic crust in the study area.

The magnetic anomalies in the study area mainly trend in the NE–SW, E–W and ENE–WSW directions, for which the NE–SW orientation predominated. The CPDs ranged between 3.0 km and 16.7 km. Shallow CPD (< 3.5 km) zones were mapped at the extreme edge of the north-western and south-western portion. The sedimentary thicknesses in the study area ranged between 1 km and 3 km. The geothermal gradient range of 34° C/km – 173° C/km and heat flow range of 87 – 446 mW/m^2 estimated for the study area indicated that there were high vertical temperature gradients and geothermal heat flow in parts of the Chad Basin. The magnetic forward models revealed the variation of the basement topography with the smoother Curie point isotherm level and the presence of sub-basins in the study area. Basement rocks in regions of shallow CPD were found to have richer magnetic contents than those in regions of deep CPD.

The study concluded that dry wells encountered in the Nigerian sector of the Chad Basin in the past could have been the consequence of high magnitude of geothermal heat flow ($> 200\ mW/m^2$) resulting from shallow depths to the Curie isotherm in various parts of the study area.

Keywords: Sedimentary/ Curie Point Depth/ geothermal heat flow/ geothermal heat flow/ topography/ aeromagnetic data

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Certain rock types contain sufficient magnetic minerals to produce significant anomalies in the Earth's magnetic field. The most common ferromagnetic mineral in rocks is magnetite, thus in most cases, the amounts of magnetite and related minerals present in the rock determine the magnetic susceptibility of the rock. Sedimentary rocks, for example, generally have a very low magnetic susceptibility compared with basement rocks (either igneous or metamorphic), which tend to have a much higher magnetite content. These dominant magnetic minerals in the crust exhibit a phenomenon characterized by a transition from a ferromagnetic state to a paramagnetic state at a critical temperature called the Curie temperature. At a temperature higher than the Curie temperature, ferromagnetic minerals lose nearly all magnetic susceptibility and become paramagnetic, and hence the ability to generate detectable magnetic anomalies disappears. Various ferromagnetic minerals have different Curie temperatures, but the Curie temperature for titanomagnetite, the most common magnetic mineral in igneous rocks, is approximately 580^{o} C (Trifonova *et al.*, 2007).

Airborne magnetic method has been widely employed in various local and regional scale geophysical investigation and exploration since it was developed after World War II.

Aeromagnetic data have been successfully used to study subsurface features both at deep and shallow depths for structural mapping of basement morphology, faults and near-surface volcanic rocks; geothermal investigation; archeological sites investigation; unexploded ordnance (UXO) detection; and in prospecting for minerals and hydrocarbon. To examine the thermal structure of the Earth's crust using aeromagnetic data, the greatest potential of the method lies in its ability to detect the deepest level in the crust containing materials, which create discernible signatures in a magnetic anomaly map, i.e., the depth at which the Curie temperature is reached (Bhattacharyya and Leu, 1975; Nwankwo *et al.*, 2009).

Considerable attention has been given to the spatial variation in the subsurface temperature to know the thermal structure of the earth. It is a known fact that the temperature inside the earth directly controls most of the geodynamic processes that are visible on the surface. The thermal structure of the crust determines modes of deformation, depths of brittle and ductile deformation zones, regional heat flow variations, seismicity, subsidence/uplift patterns and maturity of organic matter in sedimentary basins (Dolmaz *et al.*, 2005). Geothermal gradients are very useful as indicators of subsurface temperature distribution; in the understanding of regional and subregional tectonics; and in the assessment of geothermal resource potentials of an area (Nwankwo and Ekine, 2010). The temperature-at-depth is one of the primary factors controlling hydrocarbon generation, sediment diagenesis and migration of hydrocarbons and other pore fluids (Nwankwo and Ekine, 2010). Although lithospheric thermal gradients are often estimated from near-surface heat-flow measurements, but high-quality heat-flow measurements are sometimes contaminated by local thermal anomalies; are rarely distributed geographically evenly; and are often insufficient to define regional thermal structures (Tanaka *et al.*, 1999; Ross *et al*., 2006). On the other hand, determination of the Curie point depth based on spectral analysis of magnetic anomaly data (Spector and Grant, 1970; Bhattacharyya and Leu, 1975; Okubo *et al*.,