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BASIN SUBSIDENCE, SEDIMENT DECOMPACTION, AND BURIAL HISTORY MODELLING TECHNIQUES:

APPLICABILITY TO THE ANAMBRA BASIN

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ABSTRACT

A discussion of some burial and thermal history modelling techniques is given, together with the applicability of these to some sedimentary basins in Nigeria. The mechanisms of basin formation discussed follow the basic concept that basin subsidence is an isostatic response to thinning of the crust and cooling of a thermal anomaly. The rate of subsidence is mainly a function of the cooling rate, further modified by additional load related to replacement of sea water by accumulating sediments. Compaction effects during sediment diagenesis are discussed. As a result of differential compaction, the geometry of strata in a sedimentary basin changes continually during progressive burial. Thus, a stratigraphic cross section constructed from present bed thickness may differ substantially from the cross section at the time of deposition. Decompaction studies are also important in basin analysis because of the thermal effects associated with the compaction process.

The isostatic subsidence model has been applied to determine burial history curves, temperature - time, and temperature - depth relations for sediments of the Cretaceous Anambra basin of Nigeria. With subsidence assumed to have started about 80 million years ago (i.e. in the Santonian), the model study predicts maturation at fairly shallow depths of 1.5-2.0km, and overmaturation at depths below 4km, a distinct contrast with the case of the Niger Delta Basin. The predicted geothermal gradients, level of organic maturation, and subsidence data are quite compatible with information so far available from the Anambra basin.

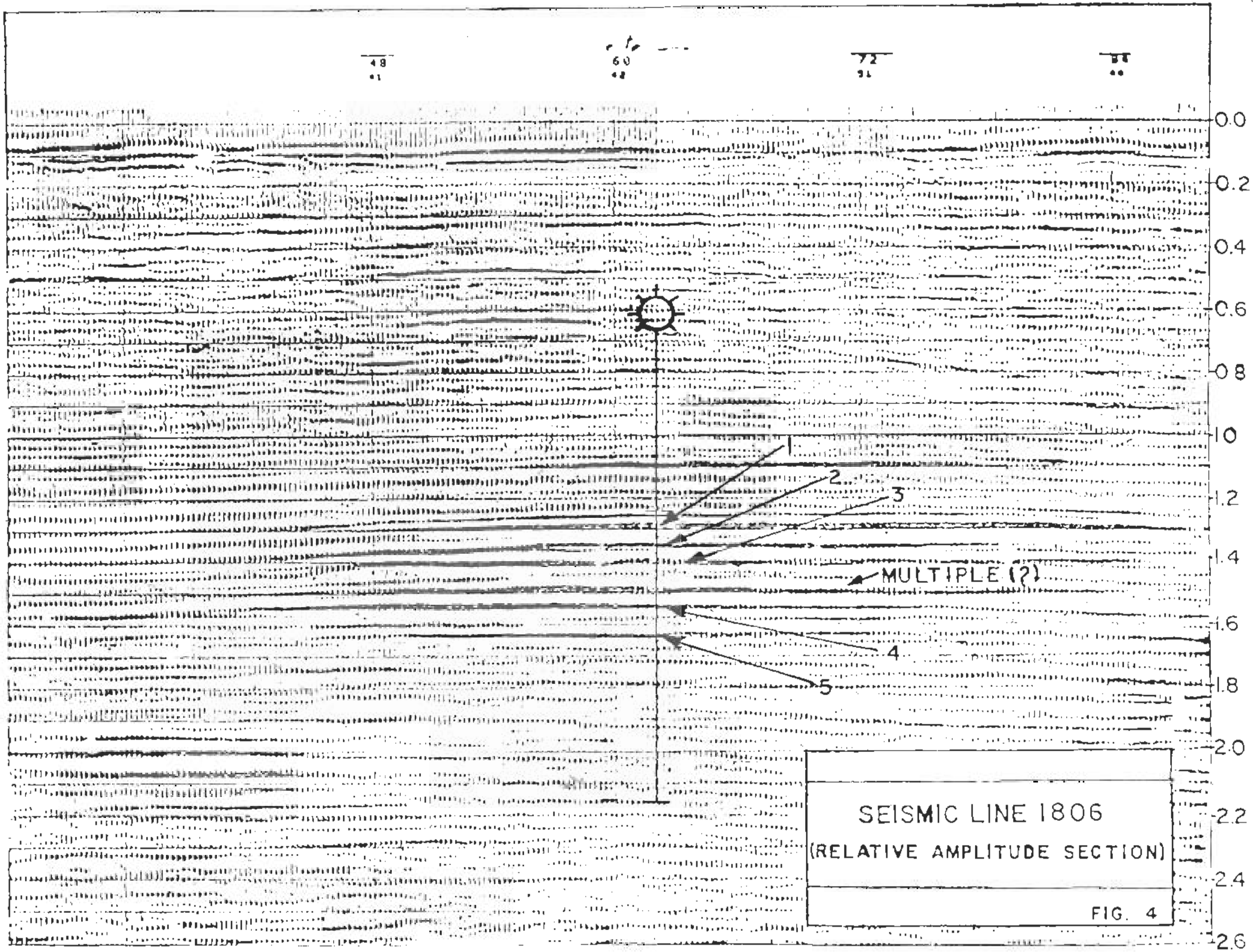
INTRODUCTION

In frontier areas of petroleum exploration activities, efforts are being made to acquire at minimum cost the information necessary for the successful location of productive wells. In the assessment of the hydrocarbon potentials of a sedimentary basin, one of the latest tools of the petroleum explorationist is the determination of the oil and gas potential of a basin from the burial and thermal histories of the sedimentary rocks contained in the basin. Taken together with information acquired from seismic stratigraphic studies, subsidence and thermal histories provide a basis for the assessment of the depth to the hydrocarbon-generative window or the determination of the level of organic maturation in the basin, even when the area is yet to be tested by drilling.

In Nigeria, onshore sedimentary basins occupy an area of about 461,000km^2, which is approximately about half of tbe total surface area of the country. Fig. 1 is a generalized geological map showing the various sedimentary basins in Nigeria. Known petroleum potential of the country is concentrated mainly in the southern part with the most petroliferous portion being proved to be beneatb the Niger Delta basin. The petroleum prospects of the various basins have recently been discussed in detail by Whiteman (1982). Exploration activities have intensified in the last few years not only in the Niger Delta, but also in the Anambra and Chad basins. It is expected that some time in the future, exploratory efforts would be carried to the Bida, Lower and Upper Benue basins. Geophysical measurements have already indicated that sediment thicknesses exceed 4km in several parts of the Benue basin.

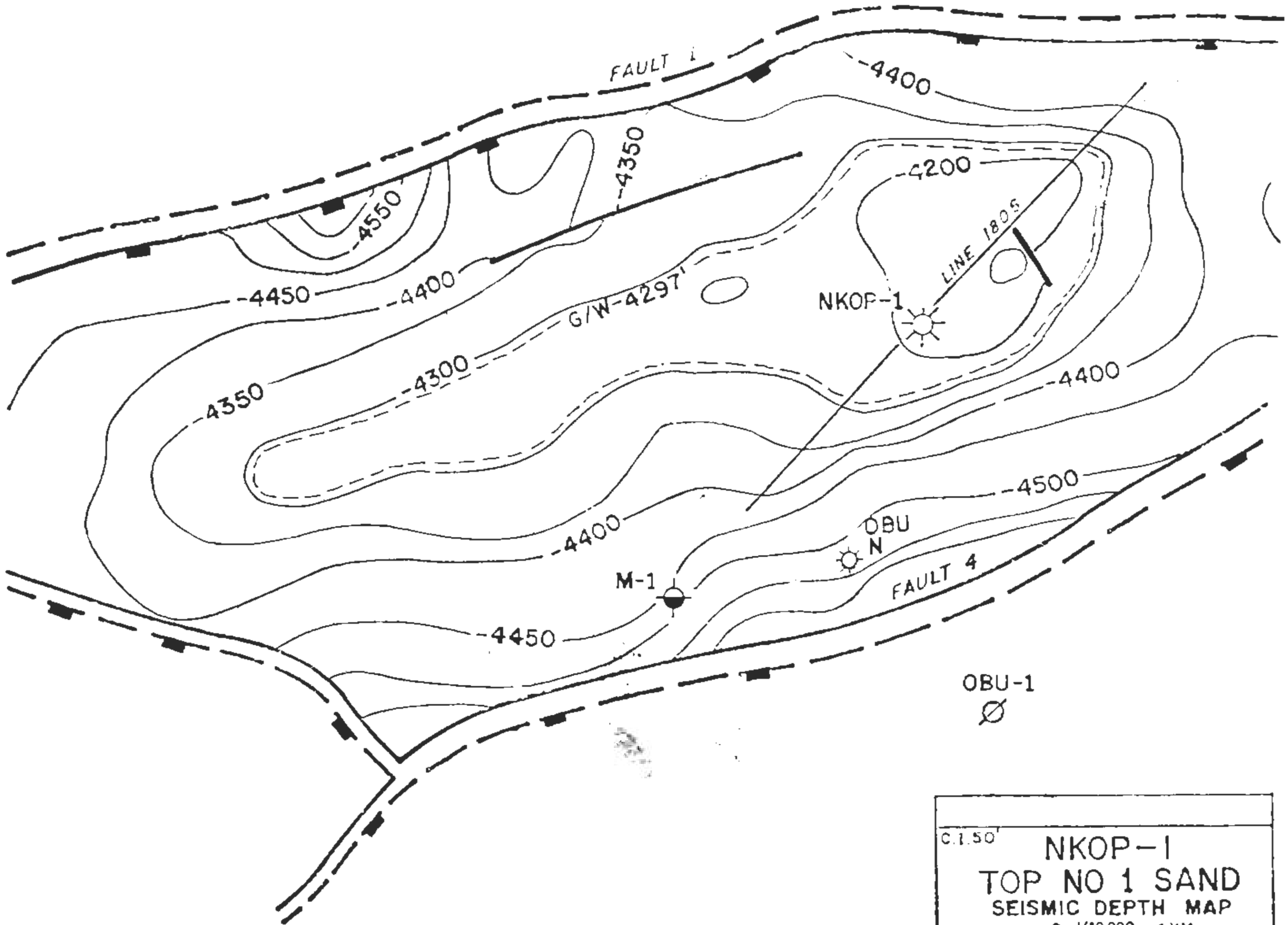
Intensive petroleum exploration and exploitation activities in the Delta region during the last two decades have led to the accumulation of a vast amount of data from which it has been possible to establish the hydrocarbon habitat and to reconstruct the history and evolution of the Niger Delta basin (Short and Stauble, 1967; Weber and Daukoru, 1975; Evamy et al, 1978). Porosity-depth relations and zones of overpressures are now fairly well established for the region (see for example, Schlumberger, 1985). The variation of geothermal gradients in the Niger Delta has also been studied (Nwachukwu, 1976; Avbovbo 1978). Similar but less detailed studies have been carried out on the Anambra basin by various authors including Avbovbo and Ayoola (1981) and Agagu and Ekweozar (1982).

The results of these studies provide a reasonable amount of data to model the subsidence, thermal and burial history of the Anambra basin.



SEISMIC LINE 1806
(RELATIVE AMPLITUDE SECTION)

FIG. 4



C.I. 50'
NKOP-1
TOP NO 1 SAND
SEISMIC DEPTH MAP
0 1/50,000 1KM
FIG 3

4. The anomalous events on the seismic line 1806 were produced by relatively large acoustic impedance contrasts between the shale-gas sand and gas-water sand interfaces.

   It is observed that the shale to gas sand interface in the geologic model has a relatively high negative reflection coefficient (–0.158), and produces high amplitude white trough in the corresponding synthetic seismogram.

   The gas sand to water sand interface has a relatively lower positive reflection co-efficient (0.155), producing a black peak. The water sand (2.24 grams per cubic centimeters) is denser than the gas sand(2.17 grams per cubic centimeters).

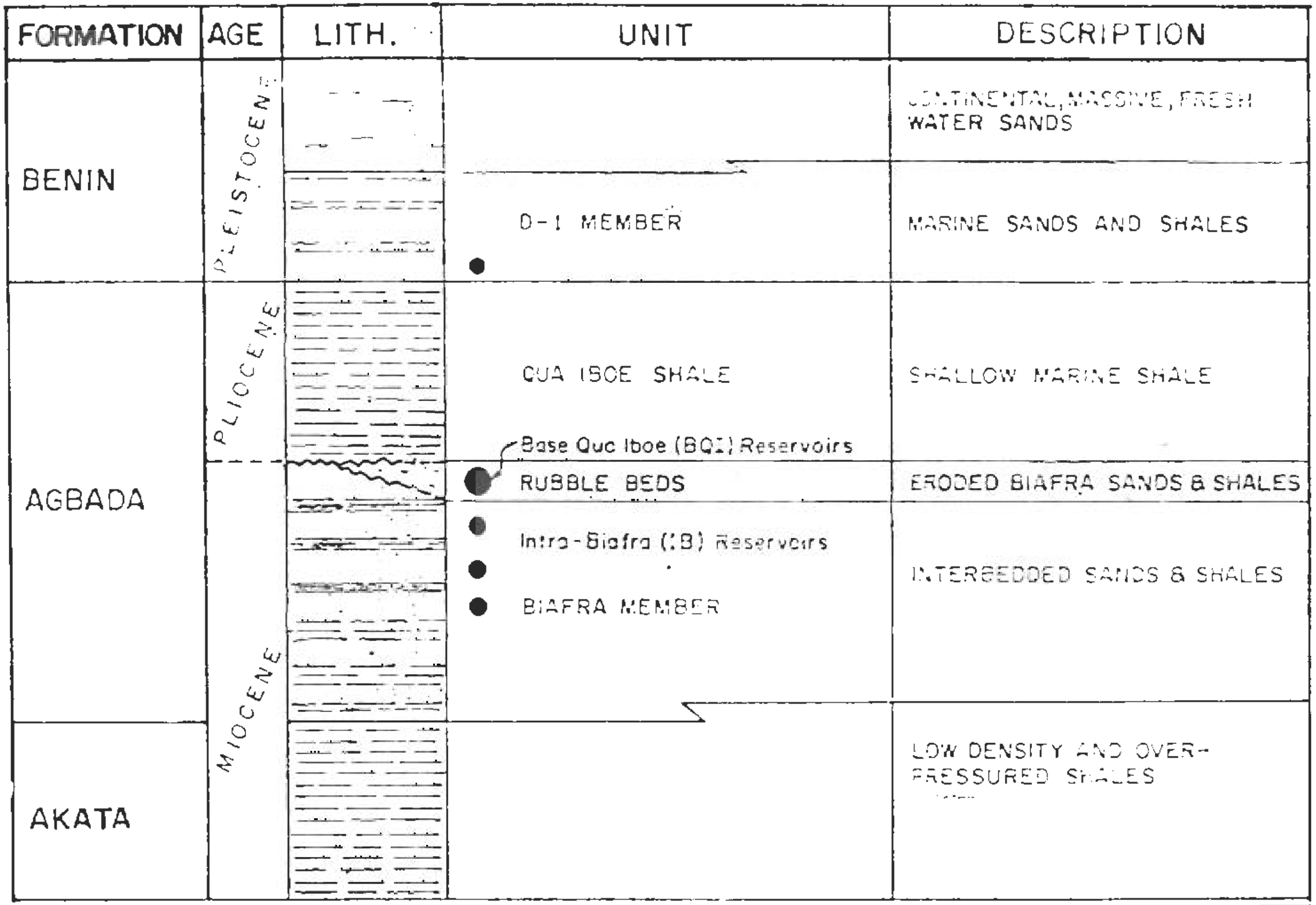
5. The study also confirmed previous knowledge about offshore fields. In the same hydrocarbon pool gas HCIs are displayed as high amplitude events on seismic records while oil sand seismic events are usually not as prominent (Figures 9, 10).

   Addition of oil into the No. 4 sand resulted in amplitude reduction in the synthetic reflections.

6. The modeling technique surely enhances seismic interpretation. Gas sands as thin as 8.5 meters can possibly be indentified using this method. A gas cap was observed on the synthetic record corresponding to the third case where 10.7 meters of gas on 15.2 meters of oil on water were substituted in the No. 4 sand (Figure 11, 12). The oil leg and the remaining part of the structure below the gas cap are not so easily identifiable on the synthetic record.

   The usual problem in Niger Delta fields is how much oil leg can be associated with prospects in which gas is apparent. This technique can be used to model the gas HCI on a particular prospect (usually on structural crests) to facilitate the estimation of probable oil from the rest of the structure.

7. This modeling technique can be used to identify possible multiple events on the seismic section. A high amplitude event occurs on seismic line 1806 between the third and the fourth gas sands (Figure 5) which is not related to any of the pay zones. The event is a probable multiple resulting from possible interbed reflection of seismic energy between the first and third gas sands. Reprocessing could be adopted to verify the validity of this assumption.



STRATIGRAPHIC COLUMN
NIGER DELTA OML'S 67-70

FIG 2