RESEARCH NOTE

Color Alteration Index (CAI) of Carboniferous Conodonts from the Amazon Basin, Northern Brazil

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ABSTRACT

The Color Alteration Index (CAI) was determined on conodonts of Monte Alegre, Itaituba and Nova Olinda Formations (Pennsylvanian) from 20 subsurface and outcrop samples mostly from the Amazon Basin, Northern Brazil.

The generalized CAI map obtained shows values varying from 1 to > 5 increasing from the margins towards the center of the basin. Corresponding isograds are in general concordant with isopachs of overburden, except locally, but this factor seems inadequate to account entirely for the higher thermal levels indicated by the CAI values.

The divergence may be explained either by the present deficiency in thickness due to erosion or, more likely heating associated with Mesozoic intrusives. A wide range of CAI values within a sample or along a section can be shown to be due to the proximity of basic intrusives.

The distribution of CAI values is consistent with known occurrences of gas and/or oil in the Paleozoic section of the Amazon Basin.

Key words: Conodonts, Carboniferous, Amazon Basin

INTRODUCTION

Conodonts are microfossils of carbonate apatite composition, containing traces of organic matter that are subject to color change in the temperature range from 50° to over 600°C (Epstein *et al.*, 1977; Wardlaw & Harris, 1984; Rejebian *et al.*, 1987).

Several studies have demonstrated that conodonts, besides being extremely useful in biostratigraphy, are also of great value as indicators of organic maturation of marine rocks of Ordovician to Triassic age. Conodonts may, therefore, be used for the compilation of isograd maps for different time intervals that serve as the basis for evaluating hydrocarbon potential, regional, contact and hydrothermal metamorphism, and some types of mineralization (Epstein *et al.*, 1977; Wardlaw & Harris, 1984; Rejebian *et al.*, 1987).

Existing literature discusses the origin, calibration, and geological application of the Color Alteration Index (CAI; Epstein *et al.*, 1977) of conodonts, particularly with respect to gas, oil, metamorphism and mineral exploration. Available data indicate that the CAI varies as a function of depth and temperature, due mainly to the effect of overburden metamorphism and/or heat associated to igneous or metamorphic activities (Wardlaw & Harris, 1984; Rejebian *et al.*, 1987).

Initial results of CAI determination on Carboniferous conodonts of the Amazon Basin, Northern Brazil, were reported by Rocha-Campos *et al.* (1988) and I discuss here their possible in-

terpretation in terms of the thermal evolution of the basin.

RESULTS AND DISCUSSION

A generalized CAI map was compiled (Epstein *et al.*, 1977) on the basis of values determined on specimens extracted from 19 core samples and an outcrop sample of the Carboniferous of the Amazon Basin, including samples from Monte Alegre, Itaituba and Nova Olinda Formations. Data for only two wells are available from equivalent units of the Solimões Basin and are only included for comparison. Available control points are relatively scarce and unevenly distributed over the area and are mostly restricted to the western Amazon Basin. Results obtained are, therefore, considered as preliminary (Fig. 1).

In spite of this limitation, values of the thermal metamorphism, predominantly low, seem rather consistent with the relatively simple geological setting of the Carboniferous strata preserved in the intracratonic basin.

Information on the stratigraphy and biostratigraphy of the strata analyzed have recently been summarized by Rocha-Campos & Archangelsky (1985). The Carboniferous sequence crops out as narrow and relatively continuous belts along the northern and southern margins of the Amazon Basin (Fig. 1). The sediments, practically undeformed, except locally, are extensively developed in the subsurface of the basin, reaching a maximum thickness of over 1,500 m. Basic intrusive bodies of Mesozoic age, with maximum cumulative thickness of 500 m, are quite frequent intercalated in the Carboniferous sediments (Sampaio & Northfleet, 1973; Almeida, 1986). (Fig. 3.)

The CAI map (Fig. 1) shows values varying from 1 to > 5 (Epstein *et al.*, 1977; Wardlaw & Harris, 1984) increasing from the margins towards the central part of the basin, largely concordant with the isopachs of the sedimentary cover (Fig. 2). The isograds bend sharply and cut across the isopachs in the area of Manaus. This anomalous behavior may reflect the presence of basic intrusive bodies, but these, however, do not seem to be particularly thick in the area (Fig. 3).

Estimates of temperature in relation to overburden, on the basis of available data on the present geothermic gradient for the Amazon Basin (Meister, 1973), yielded values in general lower than the ones estimated from the CAI of conodonts (Epstein *et al.*, 1977). Therefore, though the concordant patterns of the isopachs and isograds suggest the influence of burial, this seems to be insufficient to explain the higher values of CAI that were found.

The difference could be explained by a deficit in the present sedimentary cover due to

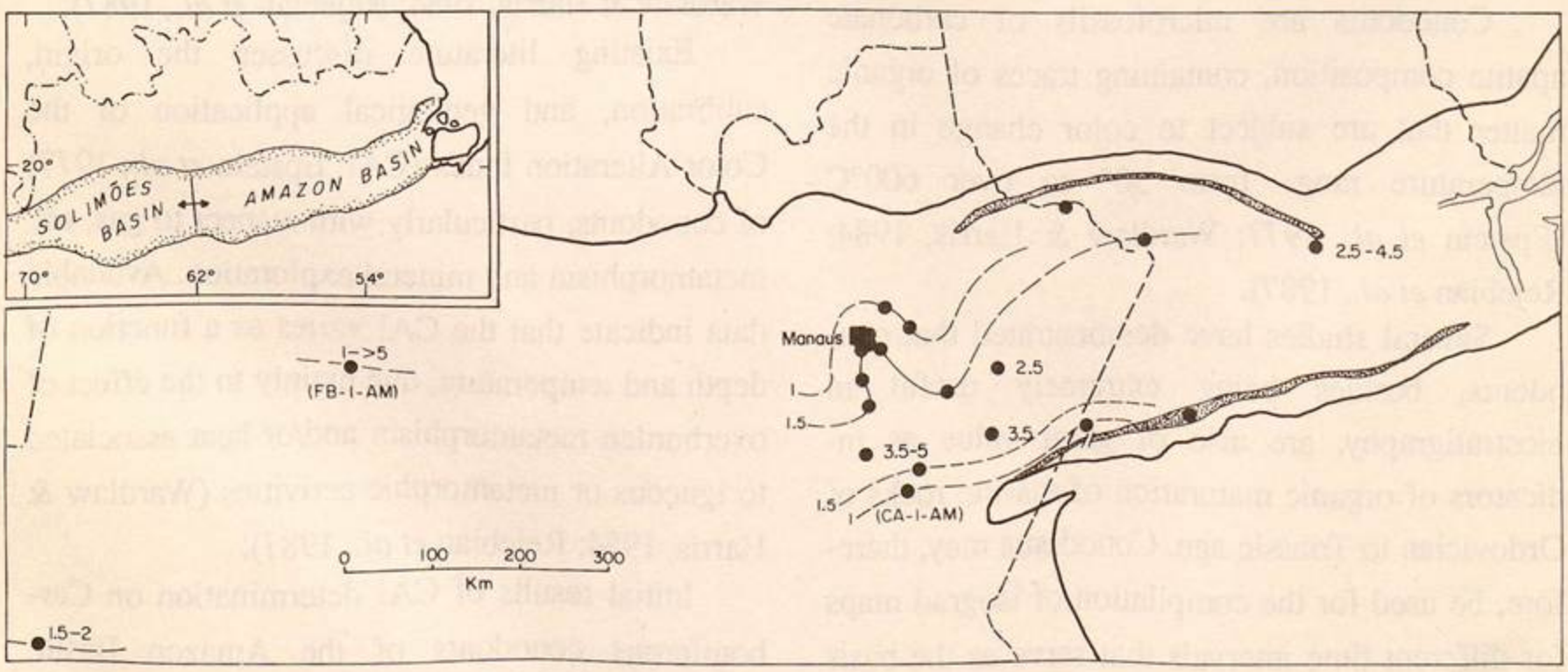

Fig. 1 — Generalized CAI isograd map for the Carboniferous of the Amazon and Solimões Basins. Thick continuous line: basin limits; dotted: Carboniferous outcrops; dashed and dotted line: international boundaries; interrupted line: state limits.

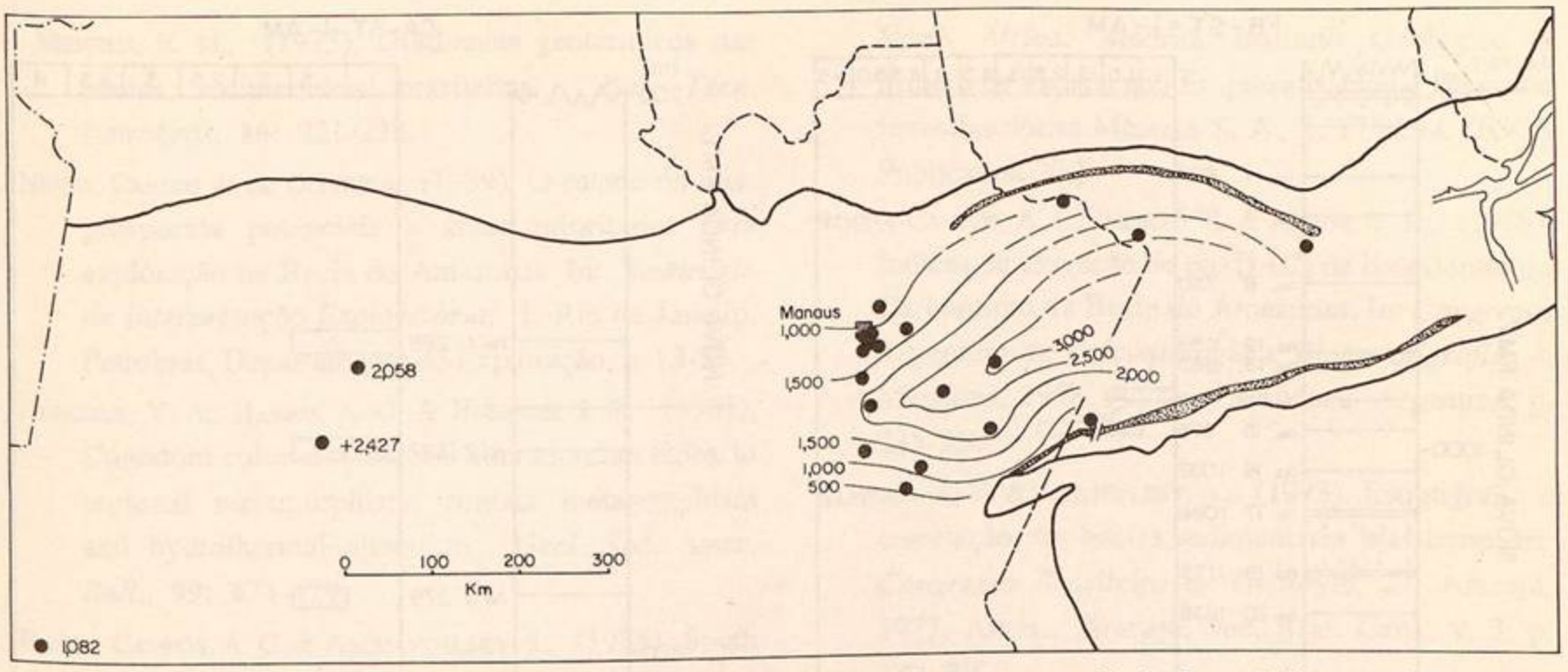

Fig. 2 — Isopachs of the Carboniferous and post-Carboniferous section of the Amazon Basin. Isopach interval: 500 m; other symbols as in Fig. 1.

post-Permian erosion (Sampaio & Northfleet, 1973). More likely, however, the level of the organic metamorphism demonstrated by the CAI is associated with a higher geothermic gradient during the Mesozoic when the basin was affected by extensive basic magmatism. The good correspondence between areas of higher values of CAI (> 2.5; Fig. 1) and of greater cumulative thickness of the Mesozoic intrusives (Fig. 3; Almeida, 1986, p. 331) supports this interpretation.

Additionally, the local thermal effect of the basic intrusives is clearly shown by the variation of the CAI of Carboniferous strata drilled in the basin. At well FB-1-AM, for instance, the CAI varies from 1-1.5 up to > 5 when approaching diabase sills (Fig. 4). The great variation of CAI between samples and in the same sample observed in this case is commonly associated with contact metamorphism, as pointed out by Wardlaw & Harris (1984). In contrast, the CAI does not show any significant variation along about 300 m of sediments drilled at well CA-1-AM, where intrusives are absent (Fig. 5).

Potential hydrocarbon source rocks seem to be rare in Monte Alegre, Itaituba and Nova Olinda Formations, which are mostly made up of sandstones, carbonates and evaporites deposited in an aeolian to shallow marine environment.

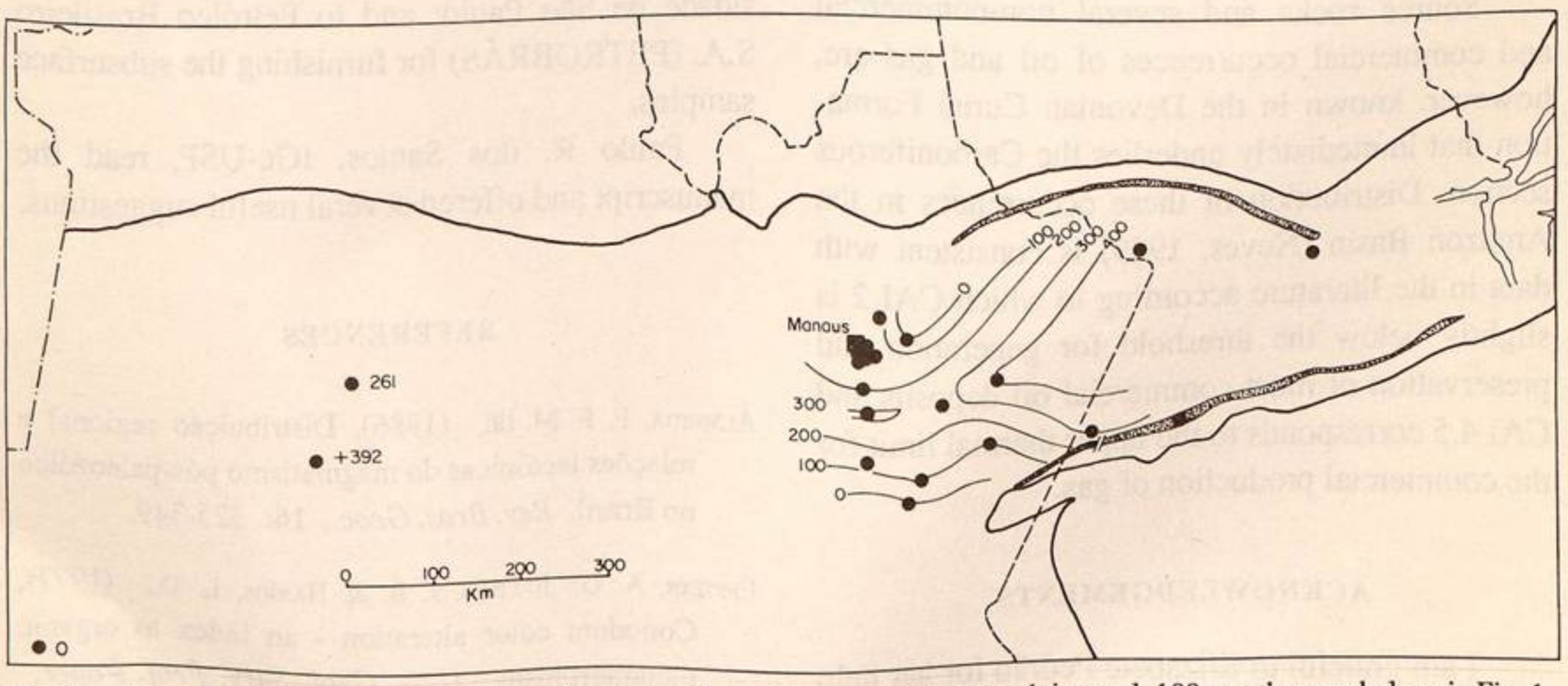

Fig. 3 — Isopachs of the Mesozoic basic intrusives in the Carboniferous section. Isopach interval: 100 m; other symbols as in Fig. 1.

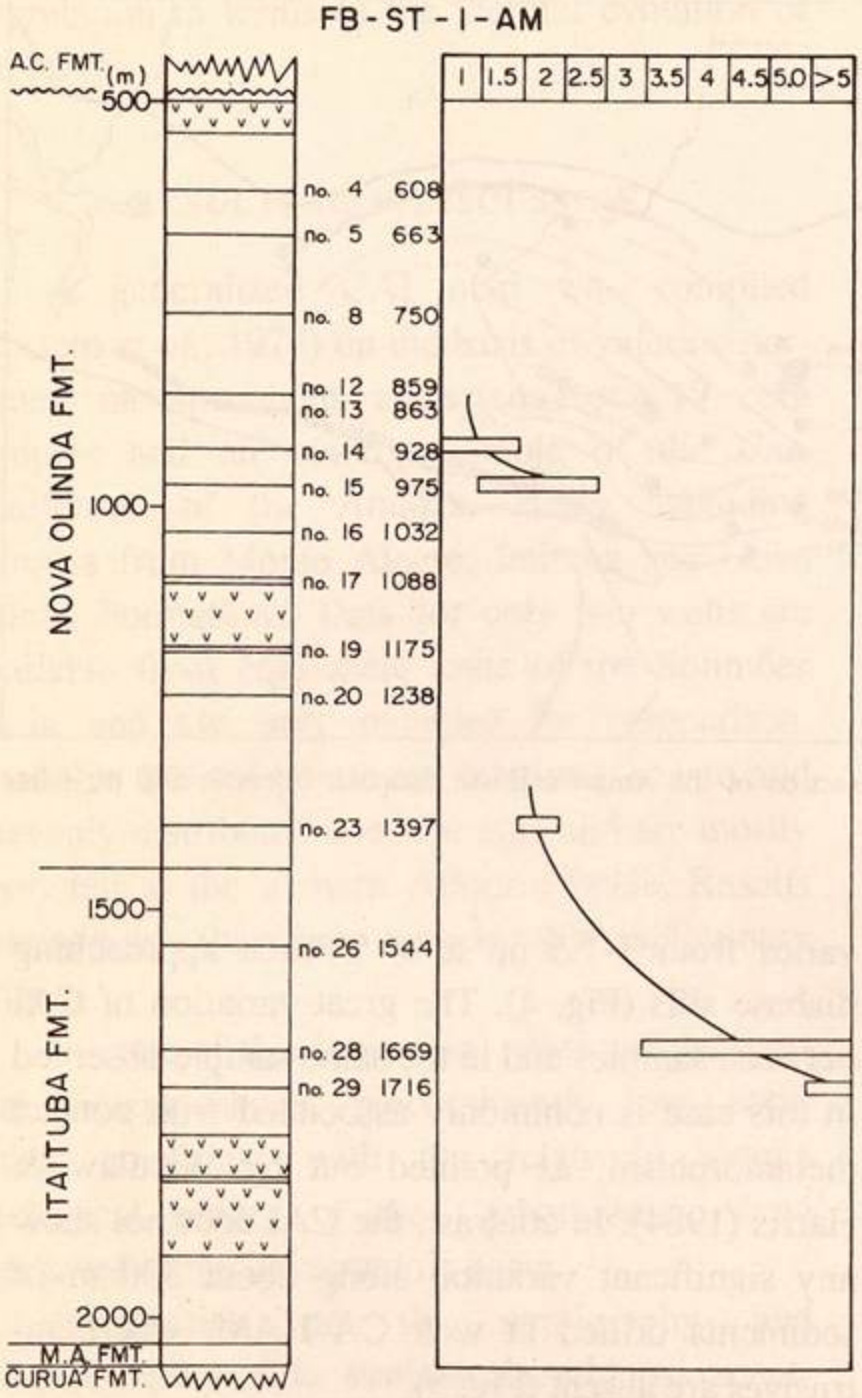

Fig. 4 — Vertical variation of CAI at well FB-1-AM (Fig. 1). Note increasing values towards intrusives. M. A. FMT.: Monte Alegre Formation; A. C. FMT.: Alter do Chão Formation (Early Cretaceous); Vs.: diabase (Mesozoic). Numbers on the right of well section refer to core number and depth.

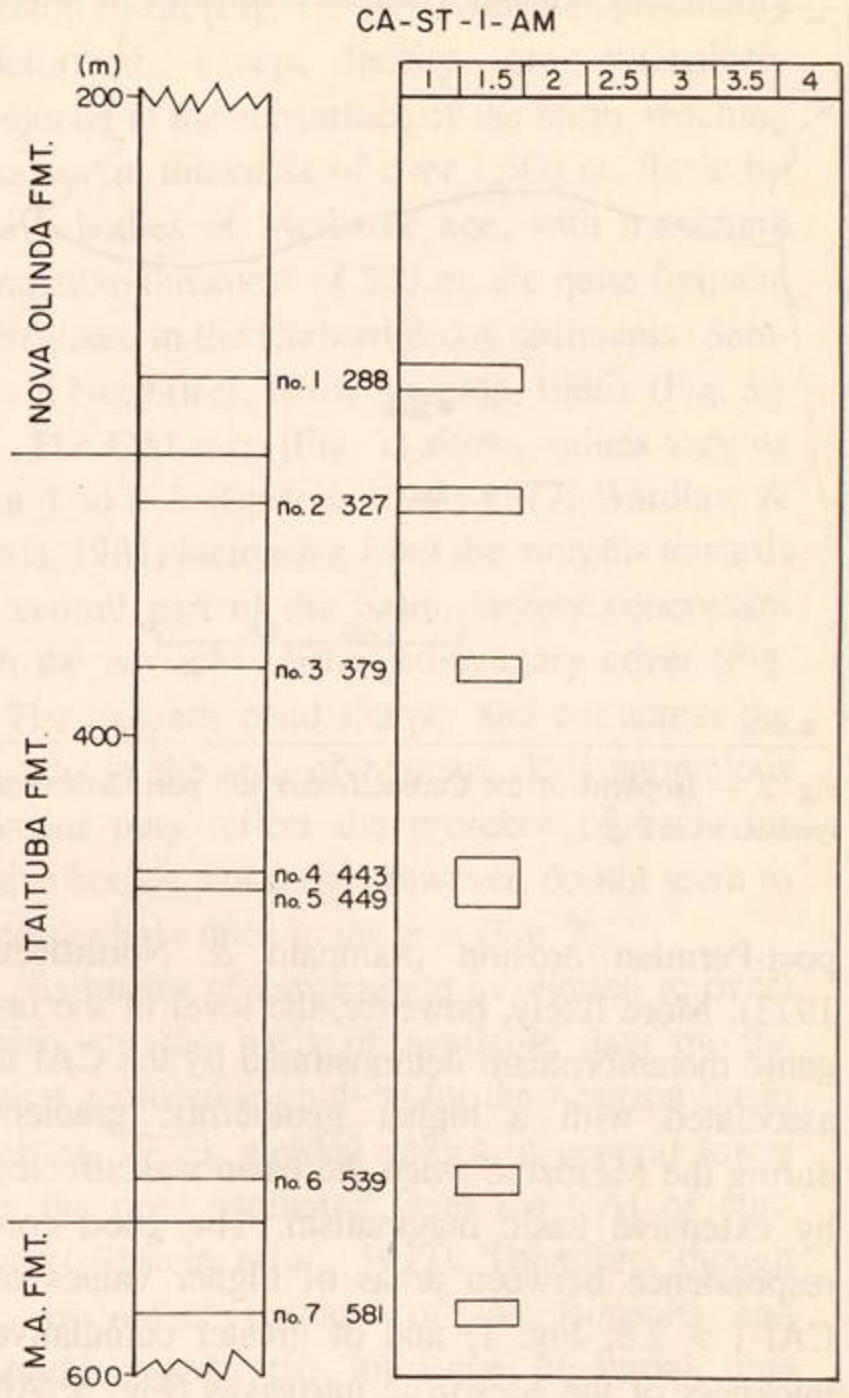

Fig. 5 — Vertical variation of CAI at well CA-1-AM (Fig. 1). Note that values do not change for about 300 m. Explanation as in Fig. 4.

Source rocks and several non-commercial and commercial occurrences of oil and gas are, however, known in the Devonian Curuá Formation that immediately underlies the Carboniferous section. Distribution of these occurrences in the Amazon Basin (Neves, 1989) is consistent with data in the literature according to which CAI 2 is slightly below the threshold for generation and preservation of most commercial oil deposits and CAI 4.5 corresponds to the upper thermal limit for the commercial production of gas.

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