doi.org/10.15392/2319-0612.2024.2578
2024, 12(4A) | 01-11 | e2578
Submitted: 2024-07-28
Accepted: 2025-02-26

Geological study of sediments from the Negro and Solimões rivers

Carvalho [a*], P. R.; Munita[a], C. S.; Soares[b], E. A. A.; Tarabossi[b], R. R. P.

[a] Instituto de Pesquisas Energéticas e Nucleares, 05508-000, São Paulo, São Paulo, Brasil.
[b] Departamento de Geociências da Universidade Federal do Amazonas, 69077-000, Manaus, Amazonas, Brasil.

*Correspondence: patricia.ramos.carvalho@gmail.com

Abstract: The Amazon is the largest and most complex ecosystem on the planet, and its entire evolutionary history was influenced by the dynamics of the Amazon River System. The geomorphological features of sections of the Solimões-Amazonas River have been studied using images from remote sensors, combined with multitemporal analysis data, and part of the sedimentary deposits is confined in four tectonic depressions that occurred during the Neomiocene-Pliocene, called hemigrábens of Paraná do Ariaú (GPA), Cacau do Pereira (GCP), Cachoeira do Castanho (GCC) and Lago do Miriti (GLM). The objective of this work was to characterize 59 sediment samples from the confluence region of the Negro and Solimões Rivers, Central Amazon using the instrumental neutron activation analysis (INAA). The experimental results obtained were subjected to cluster and discriminate analysis, revealing the formation of three groups with similar chemical composition. The differences are related to the geochemical conditions inherent in the individual depositional environments.

Keywords: Amazon, Solimões, Negro, Rivers.

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Estudos geoquímicos de sedimentos dos Rios Negro e Solimões

Resumo: A Amazônia é o maior e mais complexo ecossistema do planeta, e toda a sua história evolutiva foi influenciada pela dinâmica do Sistema Fluvial Amazonas. As feições geomorfológicas de trechos do Rio Solimões-Amazonas foram estudadas por meio de imagens de sensoriamento remoto, combinadas com dados de análises multitemporais. Sendo possivel constatar que parte dos depósitos sedimentares está confinada em quatro depressões tectônicas ocorridas durante o Neomioceno-Plioceno, denominadas hemigrábens do Paraná do Ariaú (GPA), Cacau do Pereira (GCP), Cachoeira do Castanho (GCC) e Lago do Miriti (GLM). O objetivo deste trabalho foi caracterizar 59 amostras de sedimentos da região de confluência dos Rios Negro e Solimões, Amazônia Central, utilizando a Análise por Ativação com Nêutrons (INAA). Os resultados experimentais obtidos foram submetidos à análise de agrupamentos e discriminante, revelando a formação de três grupos com composição química semelhante. As diferenças estão relacionadas às condições geoquímicas inerentes aos ambientes deposicionais individuais.

Palavras-chave: Amazônia, Solimões, Negro, Rios.

1. INTRODUCTION

The Amazon is the largest and most complex ecosystem on the planet, and its entire evolutionary history was influenced by the dynamics of the Amazon River System. In addition to Andean tectonics, the climatic and glacial-eustatic changes that occurred in the Cenozoic period have contributed to changes in the landscape of this region [1, 2]. These changes can be revealed in the sedimentary deposits of the Amazon Basin. The geomorphological features of sections of the Solimões-Amazonas River have been studied using images from remote sensors, combined with multitemporal analysis data [3, 4, 5, 6, 7]. Part of the sedimentary deposits is confined in four tectonic depressions that occurred during the Neomiocene-Pliocene, called hemigrábens of Paraná do Ariaú (GPA), Cacau do Pereira (GCP), Cachoeira do Castanho (GCC) and Lago do Miriti (GLM) [1, 4].

The objective of this work was to characterize 59 sediment samples from the confluence region of the Negro and Solimões Rivers, Central Amazon using the instrumental neutron activation analysis (INAA). The experimental results obtained had the purpose of obtaining a preliminary database with the physical and chemical characteristics of sediments.

2. MATERIALS AND METHODS

The 59 samples from seven outcrops located in the region, were collected vertically by removing material at intervals of approximately 20 cm from the base to the top [8].

The sediment samples were macerated, sieved through 100 mesh sieves, placed in an oven at a temperature of 105 ºC for a period of 24 hours and stored in a desiccator. For analysis, approximately 120 mg of each sample, with 120 mg of the reference materials Constituent Elements in Coal Fly Ash - Standard Reference Material (NIST - SRM 1633b) used as standard and Trace Elements in Soil (RM-IAEA - Soil - 7) used as reference material ×for quality control. The samples were irradiated for eight hours in the IEA - R1 Reactor at IPEN - CNEN/SP, under a thermal neutron flux of the order of 1.6×10^{12} $cm^{-2} \times s^{-1}$ [9].

Two series of measurements were carried out using a Canberra hyperpure Ge detector, with a resolution of 1.90 keV at the 1332 keV peak of ^{60}Co, an S - 100 multichannel analyzer with 8192 channels and associated electronics. After 6-7 days of decay, the following were determined: K, La, Lu, Na, Nd, Sm, U and Yb, and after 25-30 days of decay: Ce, Co, Cr, Cs, Eu, Fe, Hf, Rb, Sc, Ta, Tb, Th and Zn. The gamma radiation spectra were analyzed using the Genie - 2000 NAA Processing Procedure program, developed by Canberra.

3. RESULTS AND DISCUSSIONS

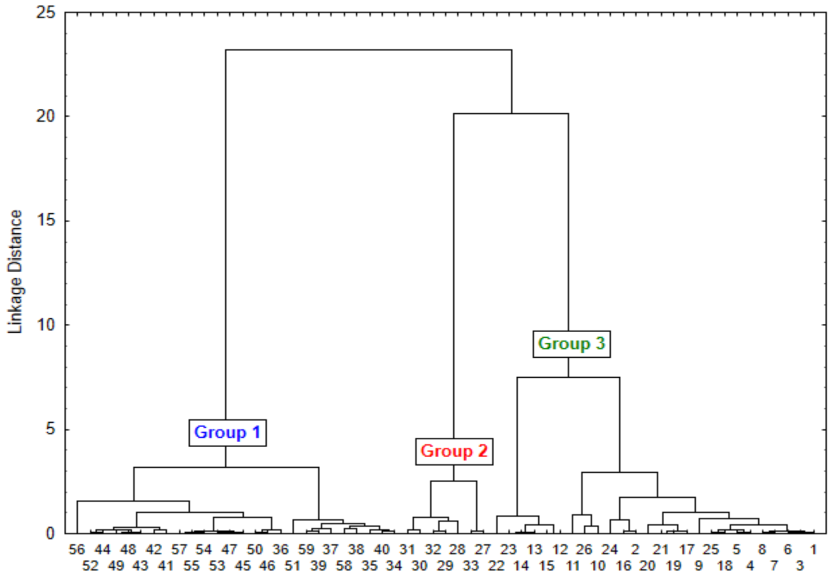
The analytical procedure used was carried out through quality control with the study of six samples of the reference material IAEA - Soil 7. The values found were compared with the recommended values. The precision of the elements Lu, Sc, Ce, Co, Cr, Cs, Eu, Fe, La, Na and Th the was ≤ 10%, this level is adequate for geological samples studies.

The results of the sediment samples were transformed to log10 to compensate the differences between the measured elements for the trace level and in percentage [10].

Geochemical studies of trace elements in sedimentary samples are useful, in particular, rare earths, because are considered immobile during weathering, transport, and sedimentation [11].

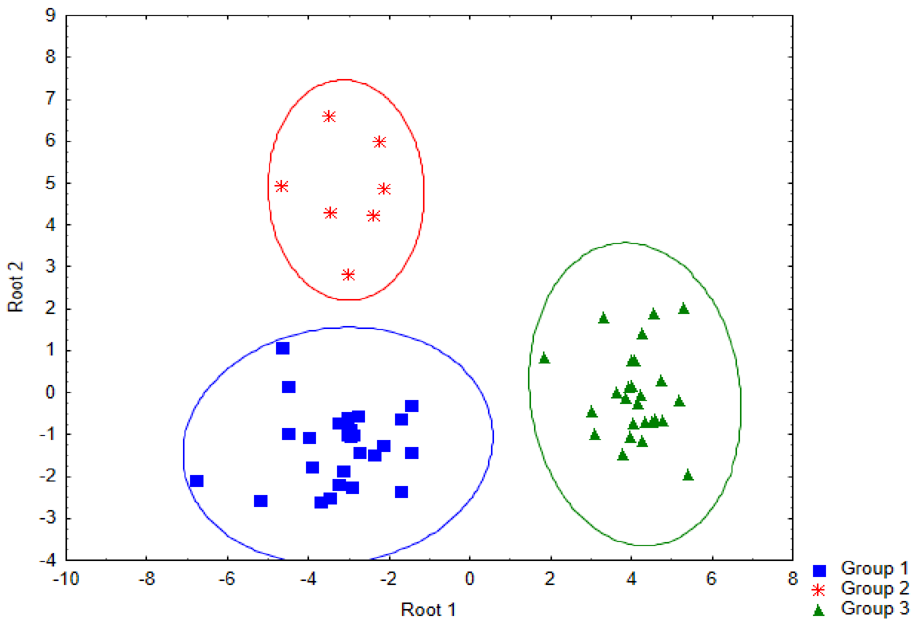
With the purpose to study the similarities/dissimilarities between the samples, the results were submitted for cluster analysis using Ward's method and Squared Euclidean distance [12]. Figure 1 shows the dendrogram where three groups of similar chemical composition can be observed.

Figure 1: Dendrogram of sample clustering using Ward's method and quadratic Euclidean distance.



With the purpose of confirming the existence of the groups, the results were submitted for discriminant analysis. Figure 2 shows the discriminant function 1 vs discriminant function 2. The results showed the separation in three groups very well defined, confirming the cluster analysis.

Figure 2: Discriminant function 1 vs discriminant function 2. The ellipse represents a 95% confidence level.



To minimize the effect of variation in the elemental concentrations of Sc, Co, Cr, Cs, Fe, Na, Ce, Th, La, Eu, Yb and Lu due to their natural abundance in sedimentary samples, the results were compared and normalized with the North American Shale Composite (NASC) procedure applied to marine-influenced deposits [13]. The mass fractions and the relative standard deviation (RSD) of the studied elements are presented in Table 1. For comparison, the concentrations for the NASC are also presented. Considering all groups studied, abundance patterns vary in relation to NASC values.

Table 1: Means and deviation for the three groups of sediments analyzed in this study, given in mg/kg, except where indicated.

	Sc	Co	Cr	Cs	Fe %	Na %	Ce	Th	La	Eu	Yb	Lu
G1	14,44 ± 3,70	21,85 ± 15,37	64,01 ± 14,88	7,49 ± 1,98	3,55 ± 2,30	0,76 ± 0,55	103,51 ± 47,23	12,61 ± 2,30	52,07 ± 22,13	2,08 ± 1,28	4,43 ± 1,78	0,69 ± 0,25
G2	9,40 ± 3,98	1,95 ± 0,30	48,75 ± 19,55	3,56 ± 2,00	1,67 ± 1,53	0,50 ± 0,21	47,00 ± 7,32	11,32 ± 1,72	28,52 ± 5,40	0,51 ± 0,18	2,92 ± 0,66	0,50 ± 0,11
G3	20,06 ± 4,03	8,36 ± 3,80	87,41 ± 15,05	10,45 ± 2,37	4,87 ± 1,89	0,11 ± 0,02	105,91 ± 30,35	15,54 ± 3,57	58,17 ± 10,07	1,80 ± 0,60	3,70 ± 0,76	0,59 ± 0,14
NASC	**15,0**	**26,00**	**12,50**	**5,20**	**4,40**	**0,75**	**67,00**	**12,30**	**31,00**	**1,18**	**3,10**	**0,46**

Figure 3: Concentrations, considering all groups in the study area, with elementary standards standardized for NASC.

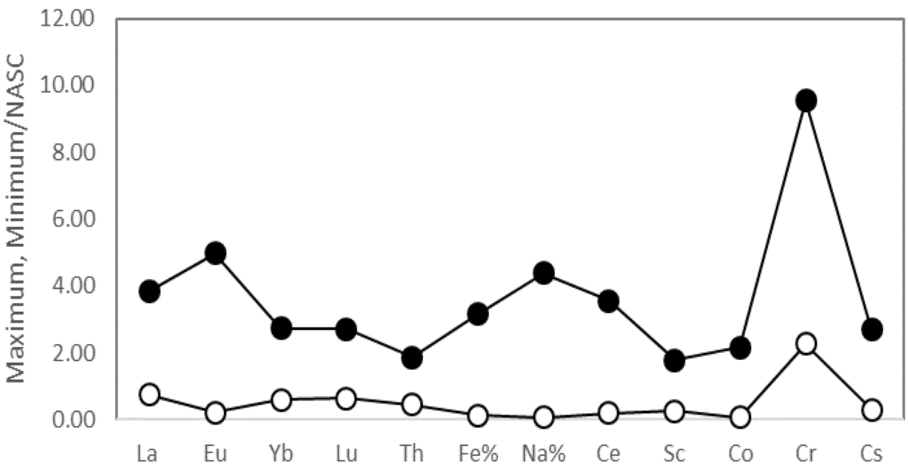


Figure 4: Average concentrations, for each of the groups in the study area, with the elementary standards standardized for NASC.

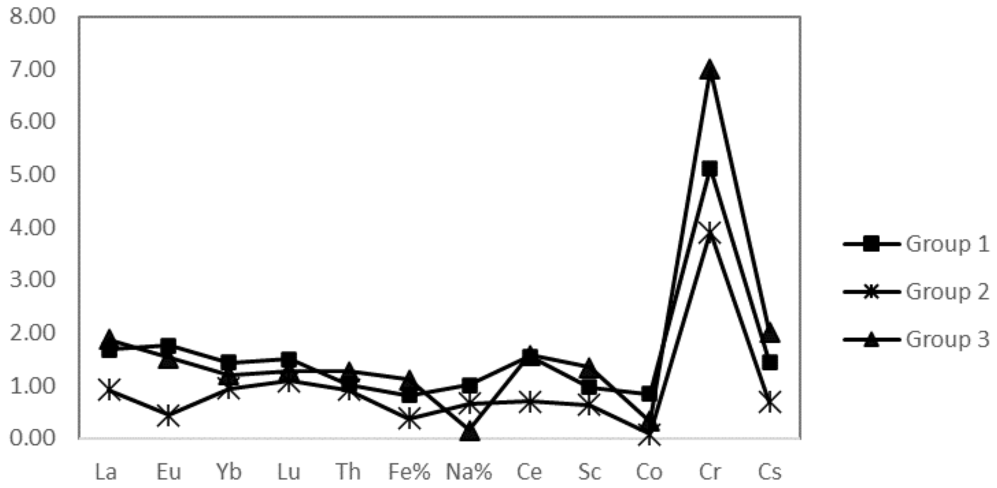


Figure 3 shows the normalized elemental standards for NASC considering the minimum and maximum concentration for all samples, and Figure 4 shows the average concentration for each group. As expected, these data revealed elemental distribution with similar patterns between the groups analyzed. The graphs also show differences in behavior when individual elements are compared between the three groups. This variation is related to deposition in environments that have lower salinity in relation to the concentration of marine sediment used as a standard. In general, high-energy, freshwater-dominated environments with high terrigenous sources, such as central river and estuarine environments, have an increased concentration of rare earths relative to marine waters [13, 14]. Several authors state that these elements are removed due to changes in the physicochemical conditions within the estuary, which is mainly due to coagulation and colloid formation under the influence of saline waters [15, 16, 17, 18].

Cesium is one of the least mobile elements in natural environments. Its occurrence in the continental crust is 1.9 mg/kg, and in seawater it is 0.5 mg/kg. This element adheres very well to soil and sediments, being 280 times better than interstitial water. Thus, a certain amount of Cs occurs in sediments, and its distribution is expected to decrease with a seaward shift in depositional environments. The higher concentration of Cs in the deposits indicates a lower marine influence in the study area, which agrees with this general statement.

The highest concentration of Cr in the groups was expected, as the occurrence of this element is favored in environments influenced by freshwater due to its preferential association with organic and colloidal material. Under low salinity in central fluvial to estuarine areas, dissolved trivalent and hexavalent Cr is flocculated or adsorbed on these particulate materials [18].

Based on the geochemical interpretation of the results the three depressions can be associated with the continuous tilting of the floors towards E-NE, which enabled the deposition of river terraces from the migration of secondary channels, it is in accordance with geochronological data in previous studies [4].

In a complementary way, sedimentary provenance analyzes carried out in deposits of the confluence zone of the Negro and Solimões Rivers, using INAA, allowed the comparison of chemical data from the depressions GPA, GCP and GCC.

4. CONCLUSIONS

In this work, 59 sediment samples were analyzed from the region of the confluence area of the Negro and Solimões Rivers. The samples were analyzed by INAA, and the results were subjected to cluster and discriminate analysis, revealing the formation of three groups with similar chemical composition.

For the samples studied, the concentration patterns of some elements relative to the NASC vary significantly. The differences are related to the geochemical conditions inherent in the individual depositional environments. This is observed by the clustering of samples in the dendrogram, as well as in the discriminant plot, where the deposits indicate that the groups are not geochemically related.

The graph of the minimum and maximum mass fractions of the elements in relation to the NASC follows a general pattern like that of the variation of the upper continental crust. The increased concentration of La, Ce and Eu relative to NASC is the evidence of deposition in a coastal to fluvial environment.

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