Spectral Remote Sensing and Digital Processing of Satellite Images for Characterizing the Iron Ores of Kanjamalai, Godumalai and Nainarmalai, Tamilnadu, India – A Case Study

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Abstract: ***This paper presents an approach to use the potential of spectral remote sensing and digital image processing of satellite (ASTER) data to identify and characterise the iron ores of Kanjamalai, Godumalai and Nainarmalai area, which forms a part of southern granulite terrain of Tamil Nadu, India. This study involves fieldwork and sample collection, geochemical analysis and digital processing of satellite images to delineate and characterise iron ore deposits of the study area. Digital processing of ASTER image includes, pre-processing, atmospheric correction, processing of image data such as simple band ratio of different band combinations were used to identify of iron ore deposits of study area. Band 5/3 + Band 1/2 combination was used to delineate Fe2+, Band 2/1 for Fe3+ and Band 5/4 for delineating lateritic deposits. The results of image analysis were compared and validated with field work and actual geochemistry of the samples, collected at random locations of the study area. This work demonstrated the potential of spectral remote sensing and digital processing of satellite images, to explore and characterise the iron ore deposits of study areas with limited field work.***

Keywords: ASTER, Spectral Remote Sensing, Geochemistry, Iron ore grade, India

1. Introduction

Satellite remote sensing techniques globally plays very important role in identifying various mineral deposits in geological prospecting, because of this satellite remote sensing techniques offers large area exploration in very short time as well as low cost, possible to identify mineral deposits of inaccessible area and mountain ranges, where we cannot do surface geological operation. This research uses remote sensing techniques for iron ore exploration and introduces the processing of satellite digital data. Identification and delineation of the spatial distribution of iron ore deposits become crucial in the exploration of mineral resources and reserves. It is also evident that the multispectral or hyperspectral sensors are effectively used to assess and characterise the surface iron ore deposits (Magendran and Sanjeevi 2013). With sufficient spatial and spectral detail for mineral exploration the remote sensing product can help in mapping the mineral deposits on a regional scale (Simon and Wielen 2005). Accordingly this study is an attempt to assess the potential spectral remote sensing and satellite image processing to delineate the resources potential of banded iron ore deposits of Kanjamalai, Godumalai and Nainarmalai of north-western districts of Tamil Nadu.

2. Study area and Geological setup

The entire study area is part of the Archean high grade granulite-gneissic terrain of South India in Tamil Nadu and contains rocks of diverse chemical and mineralogical compositions (Subba Reddy and Sashidar, 1989). Kanjamalai is one of well know banded iron ore deposits (banded magnetite quartzite) in southern granulite terrain in Tamil Nadu (Gopinathan et. al, 2015). Lithological units of the study area consist of high grade metamorphic garnet amphibole gneiss in top of the hill, flaggy nature of light colored gneiss, major and dominant ore mineral source litho unit banded magnetite quartzite (BMQ), garnet bearing amphibole, hornblendic gneiss and bottom of structural hill feldspathic gneiss, talcosic chlorite schist, light colored flaggy gneiss with garnet and without garnet are occurred, according to the stratigraphic order of superposition (GSI, 2006). Banded iron ore formation in Kanjamalai area occurred three major banded magnetite quartzite (BMQ) bands and few subsidiary bands are occurred. The lower most bands with an average thickness of 18.3 meters, over 17.7 kilometers length, middle and upper bands are 7.6 meter thickness, over 9.6 kilometer length (GSI, 2006). Godumalai area iron ore formation occurred in ridge of the structural hill trending east to west, banded magnetite quartzite occurred all alone the hill top 4.8 kilo meters length. In the hill litho units are covered by hornblende biotite gneiss in huge area, amphibolite and pyroxene granulites. Godumalai consists of banded magnetite quartzite, which has the thickness of around 3 to 5 meter stretch (GSI, 2006). Nainarmalai area located in southern granulite terrain in Tamil Nadu. Lithological units are covered by banded iron ore formation (banded magnetite quartzite) occurred all along the structural hill ridge with alternative bands of pyroxene granulite in northeastern side of V shaped hill (Subba Reddy. et. al, 1981). Banded iron ore formation occur in the form of banded magnetite quartzite with coarse grained, brownish color and magnetite bands occur as small lamina varying in thickness from millimeter to centimeter. Though the iron ores have been studied, it is necessary to map the distribution of iron ores in the study area. Figure 1 shows the locations of study sites.

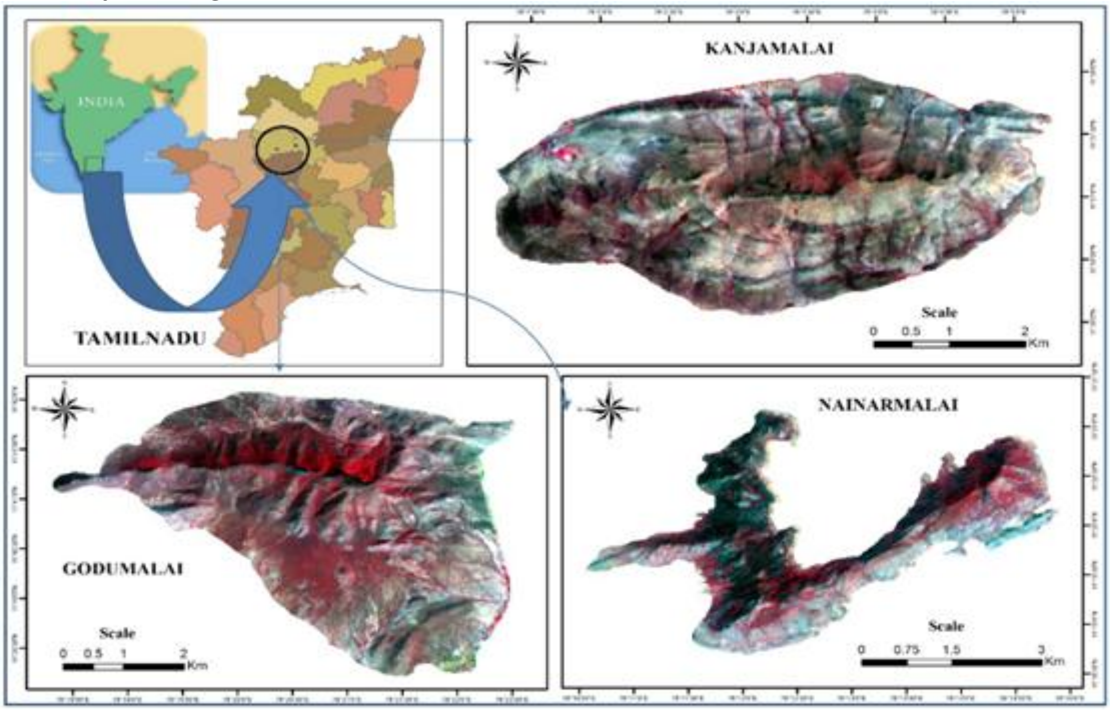

Figure 1: Location map of study area

3. Materials and Methodology

The methodology adopted in this study involves two major components, (i) satellite data analysis including multispectral image analysis, preprocessing of ASTER image, atmospheric correction, ratio maps and (ii) Geochemistry (field survey, sample collection, sample preparation for geochemistry and geochemical analysis). An overview of the methodology adopted for this study is presented as flowchart in figure 2.

3.1 Processing and Analysis of ASTER Image

Since this study aims to delineate the distribution of the iron ores of the study area using satellite images, it is necessary to remove the errors pertaining to the data acquisition such as atmospheric effects, which will considerably increase the accuracy of mapping. Since atmospheric correction has already been done by the data provider, it was not done here. The processing techniques used in this study are discussed in the following sections.

3.1.1Processing of Image Data

NDVI (Normalized Difference Vegetation Index) map is generated to obtain the distribution of vegetation in the study area, which in turn to be removed from the image to get the iron oxide abundance in the study area. Simple binary masking is carried out to remove the vegetation from study sites and spectral mapping of iron oxide. The rule is selected iteratively for ensuring complete suppression of forest or vegetation cover from study sites.

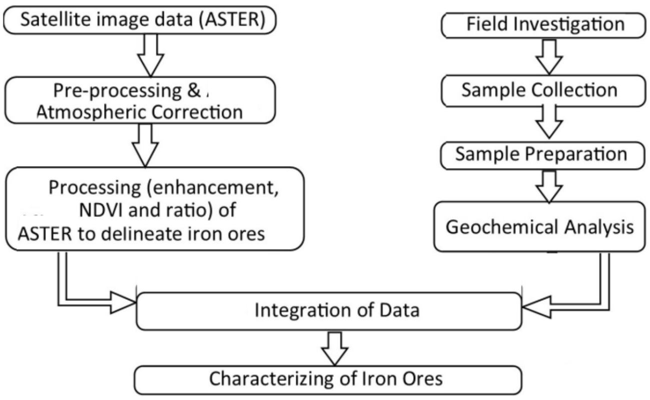

Figure 2: Flow chart showing the methodology adopted in this study

3.1.2Ratio Maps

Ratio images are knows for enhancement of spectral contrasts among the bands, which are considered in the rationing and have successfully been used in mineral mapping (Elsayed and Albielyb. 2008). Each object has its own spectral reflectance pattern in different wavelength portion. Spectral reflectance curve is a kind of fingerprint of the object. The object or rock unit may have high reflectance value in some spectral portion, however, it may absorb in another spectral region. For example, the iron ore absorb the 0.85 – 0.9 µm region of electromagnetic radiation (EMR). Band ratio is the very simple and powerful techniques for identify and demarcate the iron ore mineral deposits. The ferrous minerals abundance maps highlighted the ferrous (Fe^{2+}) minerals present in the study sites, the region highlighted in different color contrast shows the regions having maximum content of iron oxides. The banded magnetite quartzite consisting of the magnetite ridges are also clearly visible in the map (figure 4). Band ratio maps were generated using different band combination such as Ferric Fe_3+ band 2 / band 1, for Ferrous iron Fe_2+ band 5 / band 3 + band 1 / band 2 and for laterite band 4 / band 5.

Figure 3: Field photographs showing the samples collected in the study area

The next step is to validate the abundance of iron oxide content in the iron ores. To achieve this, field investigation was carried out at random locations where abundance of iron oxide has been identified using ratioing techniques. Field work, sample collection and results of geochemical analysis of these samples are discussed in subsequent sections.

3.2 Field work and sample collection

Field investigation and sample collection is an important component of this study. The ground survey has been conducted for field investigation or ground truth verification based on processing and analysis of ASTER image data. Based on the iron ore abundance map, field verification was done and various samples have been located using handled global positioning system. Total 20 sample were collected from various parts of the study sites. Care was taken during the sample collection in such a way that the samples fall in the iron ore exposure area, which was identified from satellite data. The description of the various samples collected in the study area is given in table 1. Field photographs showing the location of samples collected in the study area are given in figure 3.

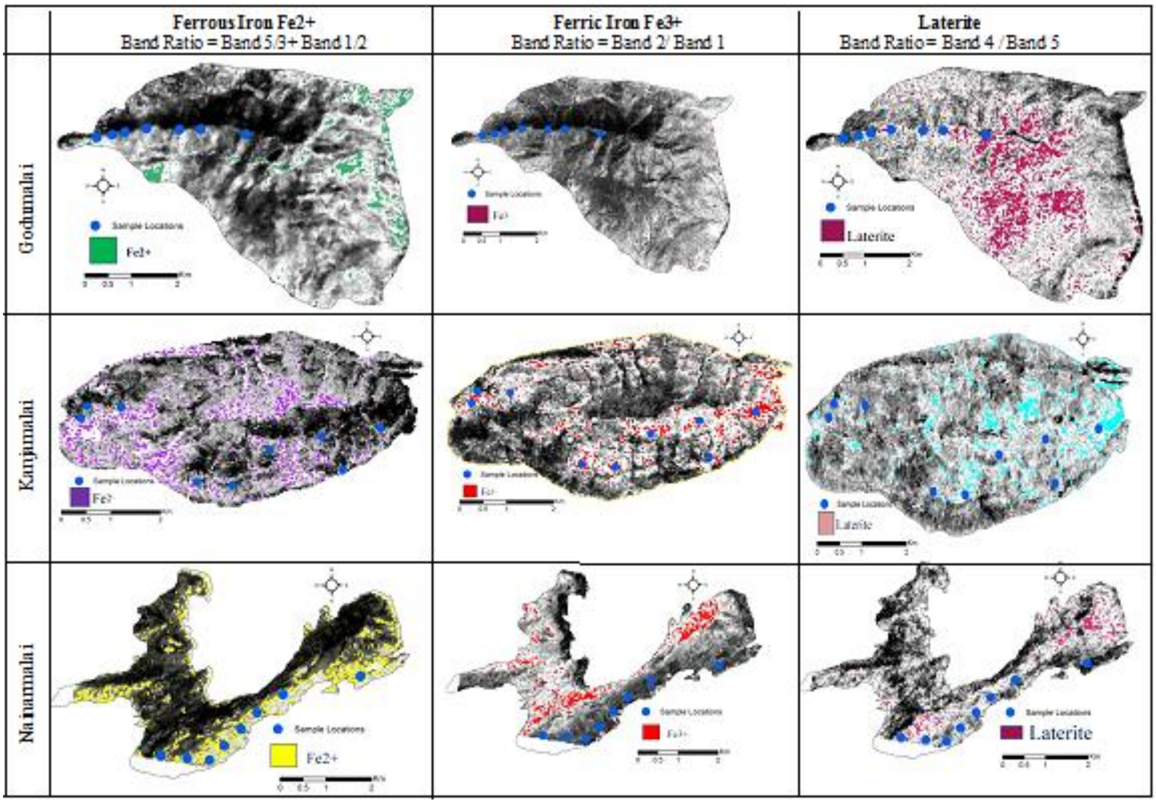

Figure 4: Iron oxide abundance map of study sites obtained by band ratios

Table 1: Description of sample collected their locations in the four study sites

Sample No	Sample Name	Sample Locations		Elevation	Sample Description
		Latitude	Longitude		
1	GS-1	11° 41' 13.3"N	78° 18' 45.6"E	443 m	BMQ
2	GS-2	11° 41' 19.7"N	78° 19' 59.6"E	461 m	BMQ
3	GS-3	11° 41' 16.6"N	78° 20' 31.7"E	475 m	BMQ
4	GS-4	11° 41' 15.2"N	78° 18' 56.8"E	476 m	BMQ
5	GS-5	11° 41' 19.4"N	78° 19' 44.7"E	485 m	BMQ
6	GS-6	11° 41' 17.3"N	78° 19' 05.9"E	492 m	BMQ
7	GS-7	11° 41' 19.9"N	78° 19' 21.0"E	503 m	BMQ
8	KS-1	11° 36' 32.4"N	78° 04' 20.3"E	334 m	BMQ
9	KS-2	11° 36' 32.4"N	78° 04' 20.3"E	332 m	BMQ
10	KS-3	11° 36' 57.8"N	78° 04' 13.1"E	348 m	BMQ
11	KS-4	11° 37' 04.3"N	78° 04' 52.2"E	364 m	BMQ
12	KS-5	11° 36' 48.5"N	78° 03' 38.6"E	380 m	BMQ
13	KS-6	11° 36' 25.0"N	78° 03' 14.1"E	392 m	BMQ
14	KS-7	11° 36' 26.7"N	78° 02' 50.3"E	407 m	BMQ
15	KS-8	11° 37' 08.5"N	78° 01' 32.7"E	302 m	BMQ
16	KS-9	11° 37' 15.9"N	78° 01' 59.5"E	305 m	BMQ
17	KS-10	11° 37' 16.6"N	78° 01' 36.5"E	341 m	BMQ
18	NS-1	11° 19' 02.7"N	78° 12' 40.1"E	240 m	Disseminated Iron Ore
19	NS-3	11° 18' 53.4"N	78° 12' 13.6"E	244 m	Disseminated Iron Ore
20	NS-5	11° 18' 54.8"N	78° 11' 54.4"E	341 m	Disseminated Iron Ore
21	NS-7	11° 19' 39.8"N	78° 13' 22.1"E	417 m	Disseminated Iron Ore
22	NS-10	11° 19' 26.5"N	78° 13' 03.4"E	285 m	Disseminated Iron Ore
23	NS-11	11° 19' 53.2"N	78° 14' 17.6"E	282 m	Disseminated Iron Ore
24	NS-12	11° 19' 14.7"N	78° 12' 52.1"E	279 m	Disseminated Iron Ore
25	NS-13	11° 18' 52.5"N	78° 12' 29.6"E	279 m	Disseminated Iron Ore

3.3 Geochemical analysis of samples

Geochemical analyses of the samples are very important since this study aims to relate the locations and abundance of the iron oxide content obtained based on the satellite data analysis and interpretations with actual geochemistry of the samples collected in the corresponding locations in the study sites. After collecting sample from field investigation and ground truth verification, various iron ore samples were powered to 100 micron size and sample were prepared for XRF analysis to identify the total iron content in the samples. The results of geochemical analysis of all the study area are presented in table 2.

4. Results and Discussion

The better spectral and spatial characteristics of ASTER image provides useful information pertaining to delineation of iron ore deposits. The removal of vegetation by masking helped in suppressing the effect of vegetation to delineate the areas having iron oxide content. From an analysis of the ASTER image, iron oxide abundance including, Ferric (Fe3+), Ferrous (Fe2+) and laterite was derived. Band rationing techniques were used to generate the abundance of iron oxide content in various parts of the study area using different band combination such as Ferric Fe_3+ band 2 / band 1, for Ferrous iron Fe_2+ band 5 / band 3 + band 1 / band 2 and for laterite band 4 / band 5.

The results of geochemical analysis of the samples collected from the random locations are correlated with the corresponding locations in the image. From the comparison it is seen that, most of the samples have high iron oxide content in the locations. This indicates that the extent of the iron ore deposits in the study area can be delineated using ASTER image data. The regions showing the maximum brightness in the ratio maps are the regions having the maximum content of iron oxide. The decrease in contrast in the gray shades in the abundance image indicates the decrease in the distribution of the iron content in those locations of the study area.

Table 2. Results of geochemical analysis of the iron ore samples of the study area

	Concentration of Component (%)										
	Al2O3	CaO	Fe3O4	K2O	MgO	MnO	Na2O	P2O5	SiO2	SO3	TiO2
GS1	1.03	1.324	37.27	0.096	2.002	0.016	0.466	0.372	56.37	0.216	0.036
GS2	0.185	1.525	40.12	0.015	2.836	0.013	0.00	0.372	54.92	0.00	0.00
GS3	1.346	1.562	36.53	0.085	2.032	0.024	0.521	0.416	54.26	0.162	0.462
GS4	0.198	1.136	44.05	0.022	1.864	0.018	0.00	0.324	52.38	0.00	0.00
GS5	0.177	1.279	45.47	0.019	2.06	0.024	0.00	0.261	50.69	0.00	0.00
GS6	1.54	1.198	39.76	0.15	1.16	0.032	0.492	0.25	57.66	0.25	0.069
GS7	17.34	5.193	4.462	2.676	2.797	0.049	6.174	0.224	60.24	0.00	0.506
KS1	1.804	0.894	36.9	0.152	1.586	0.052	0.6	0.102	56.81	0.241	0.287
KS2	14.37	14.1	12.83	0.05	7.331	0.238	2.64	0.054	47.48	0.00	0.00
KS3	1.926	0.586	38.59	0.157	1.491	0.042	0.62	0.278	57.01	0.314	0.091
KS4	0.151	0.52	48.32	0.00	2.203	0.02	0.00	0.401	48.38	0.00	0.00
KS5	2.05	3.85	24.92	0.144	1.351	0.028	0.572	0.106	66.31	0.247	0.108
KS6	2.14	0.45	50.32	0.16	1.38	0.041	0.461	0.124	45.21	0.182	0.102
KS7	2.07	0.728	39.68	0.152	1.24	0.327	0.642	0.153	57.31	0.192	0.21
KS8	12.03	16.45	15.44	0.102	8.469	0.221	1.18	0.106	45.01	0.00	0.806
KS9	2.031	0.452	25.02	0.28	1.271	0.241	0.481	0.16	64.78	0.152	0.14
KS10	12.97	13.22	13.55	0.107	12.81	0.231	1.74	0.055	44.51	0.00	0.431
NS1	4.02	12.02	24.05	10.187	5.241	0.341	0.641	0.21	37.24	0.258	1.327
NS3	8.027	13.082	22.093	15.163	6.84	0.421	0.648	0.02	35.24	0.124	0.912
NS5	7.024	16.045	18.54	9.234	0.31	0.57	0.38	0.04	37.64	0.52	0.684
NS7	4.309	12.16	22.31	0.171	8.825	0.211	0.77	0.1	36.38	0.203	1.239
NS10	0.161	0.253	54.07	0.00	1.48	0.01	0.00	0.131	43.89	0.00	0.00
NS11	3.02	2.41	35.02	5.245	0.24	0.67	0.46	0.03	36.24	0.32	0.48
NS12	0.11	0.711	44.77	0.014	1.52	0.008	0.086	0.264	52.51	0.00	0.00
NS13	1.13	0.417	39.25	0.107	0.262	0.022	0.442	0.111	50.21	0.222	0.075

The iron oxide content in the samples collected from the study sites indicates that the concentration of Fe_2O_3 varies from minimum of 4.61% to maximum of 45.47 % in Godumalai. Similarly the iron oxide content varies from a minimum of 12.83%, 18.54% and maximum of 50.32 %, 54.07% in Kanjamalai and Nainarmalai respectively. From these observations we may infer that the overall iron oxide content in the samples shows the low to medium grade based on their iron content. Further, it is observed that the spatial distribution of iron oxide content is more in Kanjamalai and Nainarmalai when compared with Godumalai. These distributions are observed clearly in the iron oxide abundance map of the study sites.

5. Conclusion

Spectral remote sensing and digital processing of satellite images provide useful information about the abundance of iron oxide in the study area. The current study showed that it is possible to detect the narrow and low iron oxide content and quantitatively estimate its spatial distribution in the ASTER image. Ratioing techniques were useful for identification of the abundance of iron oxide content including lateritic areas. This study has demonstrated that using the spectral remote sensing and digital image processing of satellite images such as ASTER data, iron ore deposits can be mapped and characterized with limited field work.

References

[1] Gopinathan P, Mohan S P and Magendran T, 2015. “Structural, mineralogical and ore grades of banded iron deposits of north-western Tamil Nadu, South India – A comparative study” International Journal of Emerging Technology and Advanced Engineering, Volume 5, Issue 3, March 2015.

[2] T.Magnendran and S.Sanjeevi, 2014. “Hyperion image analysis and linear spectral unmixing to evaluate the grade of iron ore in part of Noamundi, Eastern India” Journal of Applied Earth Observation and Geoinformation 26(2014) 413-426.

[3] Simon Oliver and Simon van der Wielen, 2005. “Mineral mapping with ASTER” AUSGEO News Issue 82, June 2005.

[4] Geological survey of India – Detailed information dossier (did) on iron ore in India 2006.

[5] Subba Reddy.N, Pulla Reddy.V, Annamalai A and Prasad.C.V.R.K, 1982. “Mineralogy and chemistry of the iron ore of Nainarmalai – Tamil Nadu” Indian academic science (Earth planetary science) Vol.91, No 1 March 1982. Pp.55-63.

[6] Subba Reddy.N and A N Sashidhar, 1989. "Mineralogy and Chemistry of banded iron ore formation of Tiruvannamalai area, Tamil Nadu" Indian academic science (earth planetary science) Vol.98, No 2, July 1989, Pp.167-172.
[7] Y.Yamaguchi, H.Fujisada, H.Tsu, I.Sate, H.Watanable, M.Kate, M.Kudoh, A.B.Kahlc and M.Pnicl, 2001. "Aster early image evaluation" Advance in space research, Vol.28, No.1, Pp. 69-76, 2001.
[8] Arindam Guha, K.Vinod Kumar, E.N.Dhananjaya Rao and Reshma parveen, 2014. An image processing approach for converging ASTER – derived spectral maps for mapping Kolhan limestone, Jharkhand, India" Current science, Vol.106, No.1, 10 January 2014.
[9] S.Adler-Golden, A.Berk, L.S.Bernstein, S.Richtsmeierl, P.K.Acharyal, M.W.Matthew, G.P.Aderson, C.L.Allred, L.S.Jeong and J.H.Chetwynd. "FLAASH, A MODTRAN Atmospheric correction package for hyperspectral data retrievals and simulations.
[10] K.A.Elsayed Zeinelabdeina and A.I.Albielyb, 2008. "Ratio image processing techniques: A processing tool for mineral deposits, red sea hills, NE Sudan" International archives of the photogrammetry, remote sensing and spatial information science. Vol,XXXVII, Part B8. Beijing 2008.

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