Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 6, Issue 4; April-June, 2019, pp. 203-209

http://www.krishisanskriti.org/Publication.html

Earthquake Phenomenon and the Delineation of Faults/ Lineaments through Remote Sensing Techniques. A Case Study from Himalayan Segment

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Abstract—*The Stress buildup around the faults, eventually releases energy in waves that travel through the rocks to cause the shaking that we feel during an earthquake. However, the delineation and mapping of these faults through which the earthquakes occur can be significant in managing the disaster effects. Though the delineation of faults in inaccessible area remain challenging, an attempt was made to delineate these structures by the remote sensing techniques and interpretations. The satellite data including Landsat ETM+, Landsat8 OLI, Landsat PAN, LISS IV and Digital Elevation Models were used to evaluate the Lineament/Fault map and to calculate the tectonic stress direction in the region. Different enhancement techniques were applied on datasets to better distinguish the structures using various filters while Laplacian and sobel filtering to enhanced data were found most convenient. The 36 lineaments/Faults were identified and their latitude, longitude and the strike were analyzed by rose diagram to assess the regional deformation and the stress direction of the region. The delineated features were found striking in NW-SE direction indicating the nature of stress direction in the region. The Drainage maps generated evaluated dendritic drainage pattern and imply dominant uniform rock type in the region.*

1. INTRODUCTION.

The mapping of geological structures improves the existing knowledge and express the significance ofRemote sensing acquisitions and interpretations for the rugged mountainous regions through. A method for tectonic lineament extraction using MOLA DTMs was previously outlined[8]. Also high spatial and better spectral resolution was used to recognize deformation structures in Himachal Pradesh having tectonic significance in a better and reliable way [4]. Further the application of remote sensing technology cover many fields of studies, such as structural geology, mineral exploration and is also useful for lineament and structure features extractions [1].[4] used high spatial and better spectral resolution to recognize deformation structures in Himachal Pradesh having tectonic significance in a better and reliable way. [3]utilized digital Landsat TM data for automatic lineament extraction in arid regions of East GabalNukra region of south eastern Egypt. . The aim of this study is to approach for delineation of structural discrepancies in order to make the detailed observations for researchers easy and reliable and therein validate the importance of remote sensing in inaccessible mountainous regions.The Himalaya, the highest mountain range in the world form a well-defined arc to the north of the Indian peninsula, extending for about 2,500km long from northwest to southeast and features the world’s youngest Orogenic belt over the time interval of 60-50 Ma [6]. Geologically, Himalaya serves an excellent example of continent-continent collision mountain belt. It has formed as a result of northward drift of the Indian plate from southern hemisphere (Gondwanaland), subduction of intervening oceanic crust of Neo-Tethys followed by the Tertiary continental collision between the Indian and Eurasian continent over a time span of 200 to 50 ma years ago [7]. The present topographic relief of the Himalaya is attributed to continue convergence of Indian plate beneath theEurasian plate and thereby remain the earthquake hazards. The present work was carried out in Suru valley, a part of NW-Himalaya, to delineate Fault/Lineament map using various modern remote sensing and GIS techniques and to analyze the direction of stress and to understand the nature of tectonic movement in the region. The region is situated along thenorth-eastern foothills of the great Himalayan Wall, and extends at 34°02′N, 76°16′E at an altitude of 3990meters (Fig 1).

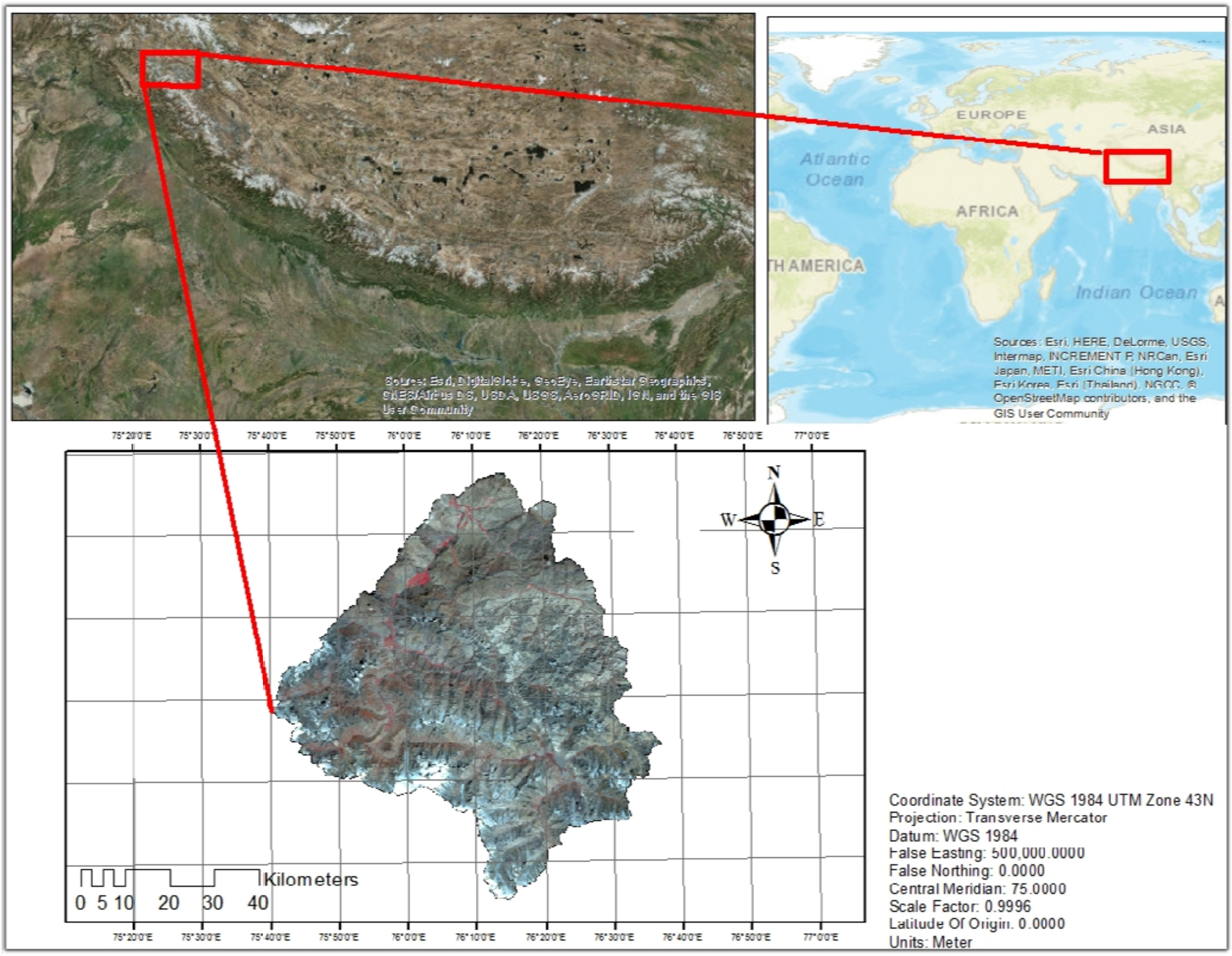

Figure 1: Map showing the location of study area

2. METHODOLOGY.

The study followed concentrated approach to yield significant results through the advance of computer based remote sensing and GIS techniques. The study used satellite imageries, GIS software's, Ancillary data and potential of ground truth. Landsat8OLI and Landsat ETM+PAN were used in the present study to map the Lineaments/Faults of the study area. The interpretations were also applied to LISS IV and Digital elevation models with varying resolutions through the use of various software's which were used in most of the study like Arc GIS, ENVI, Erdas Imagine and Global mapper. Landsat ETM (enhanced thematic mapper) and Landsat ETM+ panchromatic image (PAN) were preprocessed and geometrically rectified. Different band combinations were used in order to find the bands that are most suitable of mapping of different Lineaments/Faults. The whole methodology (Figure 2) was set in appropriate way in order to get concentrated results. The various techniques like edge enhancements, filtering processes, Band combinations, Geo-referencing, Digitization's and Geometric corrections have been much used in the present study. The latitude, longitude and direction of each lineament were stored during digitization for further statistical analysis. Direction of each lineament was plotted in a compass rose diagram. The resultant lineament map was compared with the ancillary data to follow the more evidences. The drainage pattern of the study area was digitized from the topographical maps and also generated through the different software's to have a better structural vision of region.

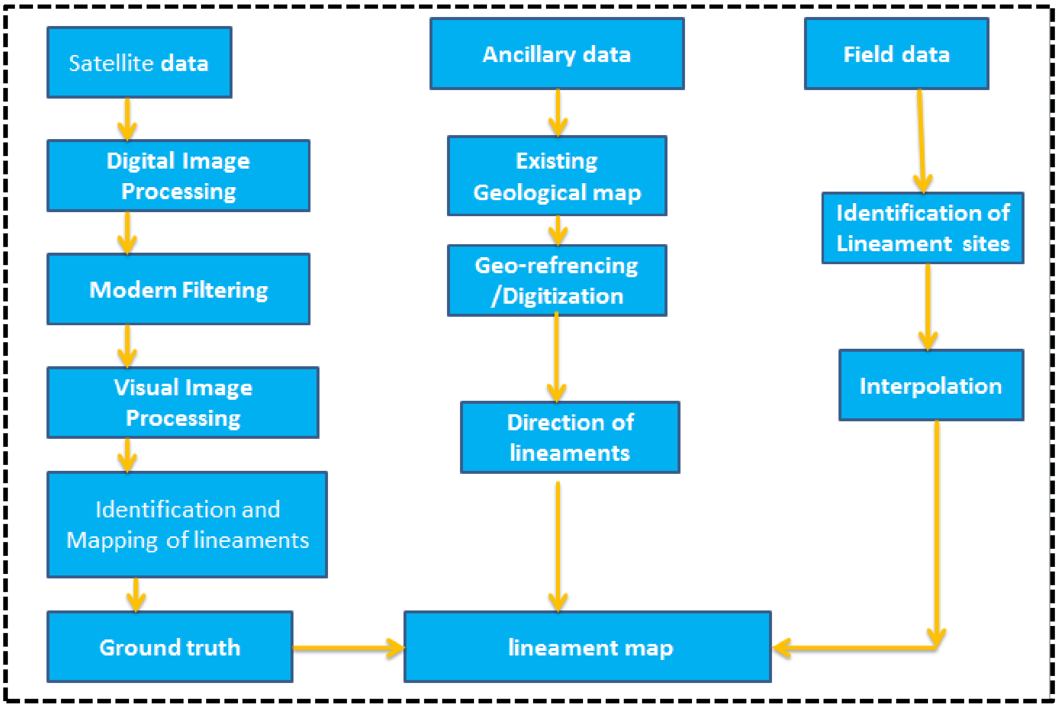

Figure 2: Methodology

3. RESULTS AND DISCUSSION.

Lineaments/Faults were mapped by the image interpretation of standard color composite (FCC) of Landsat ETM Image, LISS image and were enhanced using 3x3 edge enhancement filter, Laplacian filter and sobel filter and then merged with the PAN image of 15meter resolution. The 36 lineaments were delineated (Figure 3) and plotted on the coordinated map with the help of GIS software's. Among the all features, there are five major lineaments which have been found in the region. The maximum length among the major lineamentswas foundapproximately 9kms that lie in the centre of the study region. The other major ones have been found at the length of 7.1kms, 6.7kms, 6.6kms and 6.4kms. However there are 9 lineaments whose length have been found varying from 3kms to 5kms. All the other lineaments have been found below 3km length and though become less concern for the earthquake structural discrepancies. The latitude longitude and direction of all possible Lineaments were stored during digitization as given in the (Table 1) to make the ground truth assessable.

The drainage pattern of the study area was digitized (Figure 4) which shows the dendritic type of drainage pattern and thereby indicating the homogeneous formation of rock types in the study region. In order to study the relation between the drainage and all other lineaments, the lineaments were overlaid over the drainage map (Figure 5) which revealed that some of important streams flow through these lineaments indicating that the drainage of the study area is structurally controlled. The results were merged with the PAN image in order to differentiate between the artificial linear features such as roads, canals etc. and the lineaments. All the lineaments were plotted in the rose diagram to analyze the directions of the regional stress. The results from rose diagram show NE-SW direction of all the features as represented in (Figure 6) which relate them with the regional Himalayan tectonic collision.

Table 1: Description of Lineaments/Faults

Lineament	Length (Mts)	Direction	Location
1	2008.52	N25°E-S25°W	34°30',34°31'N - 76°09',76°09'E
2	3960.36	N20°E-S20°W	34°30',34°32'N - 76°08',76°09'E
3	1216.81	N26°E-S26°W	34°30',34°30'N - 76°08',76°09'E
4	2790.09	N28°E-S28°W	34°03',34°04'N - 76°04',76°04'E
5	6650.33	N35°E-S35°W	34°04',34°06'N - 75°57',76°00'E
6	3071.58	N30°E-S30°W	34°05',34°07'N - 75°55',75°56'E
7	1552.67	N55°E-S55°W	34°00',34°00'N - 76°07',76°08'E
8	3761.35	N55°E-S55°W	34°24',34°25'N - 76°00',76°01'E
9	912.01	N40°E-S40°W	34°26',34°26'N - 76°02',76°02'E
10	2239.77	N85°E-S85°W	34°10',34°11'N - 76°26',76°27'E
11	2301.18	N20°E-S20°W	34°09',34°10'N - 75°44',75°44'E
12	3635.12	N45°E-S45°W	34°01',34°02'N - 76°15',76°17'E
13	1389.93	N44°E-S44°W	34°20',34°21'N - 76°05',76°06'E
14	1408.21	N46°E-S46°W	34°20',34°20'N - 76°07',76°08'E
15	4653.54	N40°E-S40°W	34°31',34°32'N - 76°14',76°17'E
16	1565.46	N62°E S62°W	34°14',34°15'N 75°56',75°57'E
17	907.71	N20°E-S20°W	34°17',34°18'N - 75°57',76°57'E
18	856.34	N45°E-S45°W	34°10',34°11'N - 76°10',76°10'E
19	1594.89	N60°E-S60°W	34°22',34°22'N - 76°15',76°16'E
20	1581.98	N22°E-S22°W	34°23',34°24'N - 76°23',76°23'E
21	881.58	N20°E-S20°W	34°23',34°23'N - 76°21',76°21'E
22	787.45	N35°E-S35°W	34°03',34°03'N - 76°07',76°08'E
23	2063.35	N05°E-S05°W	34°30',34°31'N - 76°14',76°14'E
24	2175.32	N85°E-S85°W	34°28',34°28'N - 76°16',76°16'E
25	6436.55	N35°E-S35°W	34°04',34°06'N - 75°53',75°56'E
26	3187.31	N80°E-S80°W	34°26',34°26'N - 76°58',76°00'E
27	1904.3	N25°E-S25°W	34°35',34°36'N - 76°12',76°12'E
28	1919.41	N15°E-S15°W	34°35',34°36'N - 76°12',76°13'E
29	3696.23	N65°E-S65°W	34°33',34°34'N - 76°12',76°14'E
30	2451.02	N39°E-S39°W	34°34',34°34'N - 76°08',76°09'E
31	3698.19	N40°E-S40°W	34°29',34°30'N - 76°16',76°17'E
32	4821.67	N15°E-S15°W	34°06',34°08'N - 76°12',76°13'E
33	6747.59	N07°E-S07°W	34°07',34°10'N - 76°10',76°11'E
34	8870.86	N20°E-S20°W	34°08',34°12'N - 76°08',76°10'E
35	7127.87	N20°E-S20°W	34°08',34°12'N - 76°05',76°07'E
36	2528.85	N05°E-S05°W	34°06',34°08'N - 76°14',76°14'E

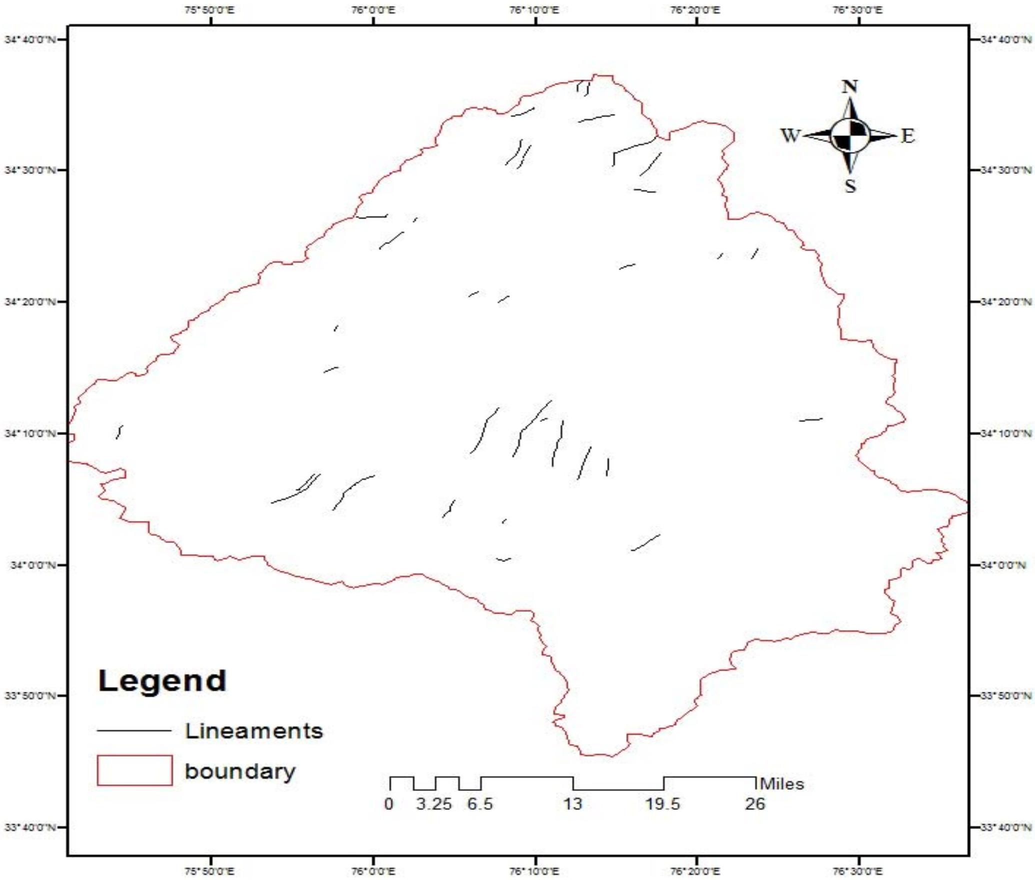

Figure 3: Map showing the Lineaments/Faults

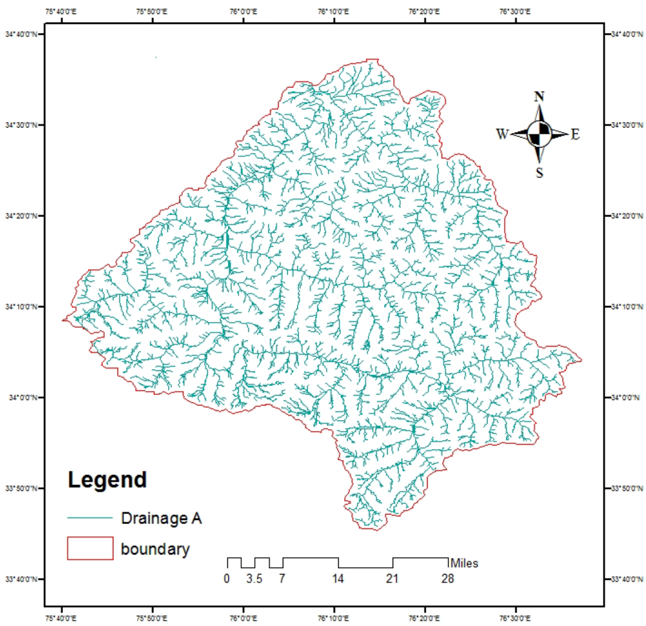

Figure 4: Drainage map

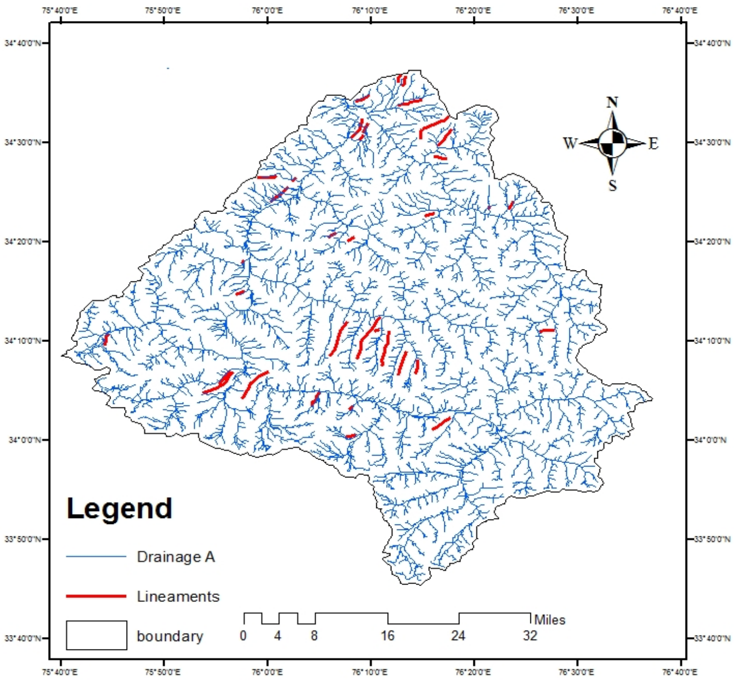

Figure 5: Comparison between Drainage and Lineaments

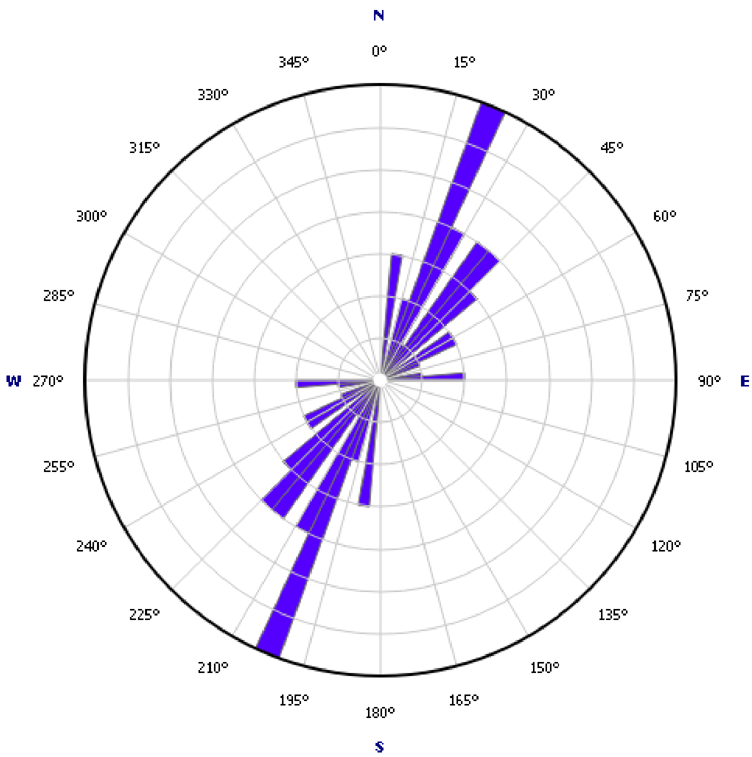

Figure 6: Strike directions of Lineaments/Faults Plotted in rose diagram

4. CONCLUSION

The study based on the approaches of remote sensing techniques and interpretations to find out the structural nature of inaccessible areas in Himalaya is significant to access the linear feature/faults and to map their orientations. The work brings out the location of faults/Lineaments and the nature of stress in the region to understand the geological scenes of the foothills of greater Himalayan belt. The technique of remote sensing interpretations has been found very substantial for mapping these structures and to produce a better vision of structural discrepancy. Also, the present work demarcated the need of integrated approach of remote sensing and GIS techniques in association with the field work to understand the significance of related work in the modern geological sciences and to make the ways easy for geoscientists to explore the detailed research.

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