Volume 68, Issue 3, 2024
Journal of Scientific Research
of
The Banaras Hindu University

# Knowledge Mapping of Scientific Literature on Ophiolite: A Comprehensive Bibliometric Analysis using CiteSpace with special reference to Naga Hills Ophiolite

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*Abstract:* **Ophiolite occurrences are not coincidental geological events. Different orogenic belts with certain age groups are associated with unique ophiolite complexes, which indicate periods of heightened ophiolite genesis and emplacement. Global events have influenced the growth of ancient ocean basins' Wilson cycles, which have aided in the genesis of ophiolite formation in various tectonic settings. Over time, ophiolite studies have contributed significantly to a better understanding of the mechanisms underlying continental expansion and the role that plate tectonics and plume tectonics played in the evolution of the crust during the Precambrian and Phanerozoic. The knowledge domain maps are plotted using CiteSpace visualization software after the time distribution feature, country/region distribution, organization distribution, main source journal distribution, research hotspots, and frontier of literature are analyzed. A visualization analysis of 7763 and 453 research articles on the ophiolites found on Global and Indian scale from 1994 to 2023 and 27 research articles on the Naga Hills Ophiolite from 2011 to 2023 was carried out based on the ophiolite research framework to provide a scientific basis for future research and to gain a deeper understanding of specific Naga Hills Ophiolite research foci and development directions. The Naga Hills Ophiolite is found in Noklak district, one of the oldest former subdivisions of the Tuensang district of Nagaland which was upgraded to a full-fledged district on January 20th, 2020, becoming the 12th district of Nagaland. The ophiolite research results, with particular reference to Naga Hills Ophiolite, indicate a global trend toward an increase in the number of published papers issued each year. India is the country with the most published papers on NHO; its Department of Science and Technology (India) sponsored the most publications but has little worldwide influence. Important journals like Geology and Lithos have contributed more to this topic. A new map of NHO was generated from QGIS 3.28.0 using Geological Survey of India toposheet No.83 K/13, 0/1, N/4 on a 1:50,000 scale as the base map**

*Index Terms:* **Bibliometric Analysis, CiteSpace, Naga Hills Ophiolite, Ophiolite, Web of Science.**

## I. Introduction

Ophiolites are often represented by a series of rocks in the litho-stratigraphic successions that most probably derived from the oceanic crust; peridotite, gabbro, sheeted dike complex, pillow basalt, and sedimentary rocks are some of them (Coleman, R. G., 1977; Dilek, Y., 2003; Dilek, Y. and Furnes, H., 2014; Furnes, H. et al., 2014). Since its initial appearance in the geological literature by Alexandre Brongniart in 1813, the idea of ophiolites has been dynamic and constantly changing. Ophiolites are of significant interest to geologists because they offer unique insight into the natural processes that take place in the oceanic crust. It aids in comprehending the geology of the Indian subcontinent and offers insights into the processes that formed the Earth's crust. The famous ophiolite complexes worldwide are the Semail

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Ophiolite (Oman), Troodos Ophiolite (Cyprus), Bay of Islands Ophiolite (Newfoundland, Canada), the Josephine Ophiolite complex (California, USA), the Ophiolite Belts in the Himalayan (Fig. 1a). The ophiolites in India are primarily located in the northern and eastern Himalayan regions of India (Fig.1b). The discovery of the Himalayan Ophiolite was significant as it provided evidence for the existence of the Tethys Ocean (Searle, et al., 1987), which was an ancient ocean that once separated the Indian subcontinent from the rest of Asia.

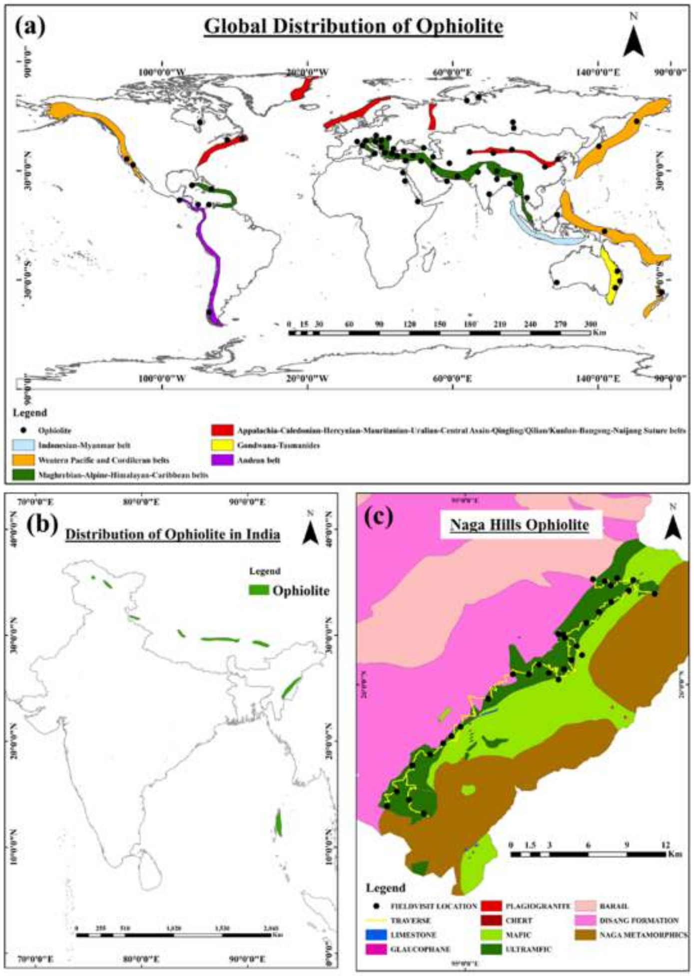


Fig. 1: a) Global distribution of ophiolite (Saccani, E. 2014), b) Distribution of ophiolite in India (Ryan, et al., 2009), c) Lithological Map of Naga Hills Ophiolite in Noklak district, Nagaland showing the lithology of Mafic and Ultramafic Group of rocks (modified from Geological Survey of India, 1974, 1975, 1980, 1982) in light and dark green. The black circles indicate the location during field visits.

The Naga-Manipur Hills in India, the Chin and Arakan Hills in Myanmar, and the Andaman-Nicobar Islands in the Bay of Bengal are all known locations of the tectonic slices of the oceanic crustal segments along the eastern margins of the Indian plate, starting from Myodia in the Dibang valley at the northern end of the Indo-Burman Ranges (IBR) (Acharyya, et al., 1990; Ghose and Agarwal, 1989; Ghosh and Ray, 2003; Ghose, et al., 2014). Understanding the emplacement of Naga Hills Ophiolite (NHO) involves determining whether they formed in a Mid Ocean Ridge (MOR) or a plate margin setting prior to the obduction of the oceanic crust (Church and Coish, 1976; Saunders, et al., 1980). Some researchers propose that the NHO originated from multiple subduction processes (Mitchell, 1993; Acharyya, 2007). Conversely, others suggest it originated in an island arc (IA) setting within the Tethyan Ocean (Bhattacharjee, 1991; Nandy, 2001). Geochemical signatures of NHO exhibit a tectonic environment of formation as supra-subduction zone (SSZ) setting (Abdullah, et al., 2018; Kingson, et al., 2017; Ovung et al., 2017; Pal et al., 2014; Verencar, et al., 2021). Others show derivation from a Mid Oceanic Ridge (MOR) setting (Ao, et al., 2020; Bhowmik and Dutta, 2021; Ghosh, et al., 2018; Khogenkumar, et al., 2021; Ningthoujam, et al., 2012; Singh, 2009, 2013; Singh, et al., 2017). The mafic and ultramafic rocks of Naga Hills Ophiolite (NHO) have a 200 km strike length that occurs almost along the Myanmar border, with 30 km of that length falling within Noklak district of Nagaland (Fig. 1c). The Noklak district is located on the eastern edge of the Indian Shield is one of the oldest former subdivisions of the Tuensang district of Nagaland. It was upgraded to a full-fledged district on January 20th, 2020, becoming the 12th district of Nagaland. The NHO is composed of fragmented tectonic slices that are located beneath accretionary wedge sediments at a convergent border where the Indian plate subducted beneath the Burmese microplate (Ghosh, 1986; Bhattacharjee, 1991; Ajoy, et al., 2017). The magnetite ore deposit in the NHO stands out from other Indian magnetite ores due to its unique ophiolitic association, igneous origin, and significant economic potential. The presence of chromium, nickel, and cobalt in the magnetite ore makes it particularly noteworthy (Vaish et al., 2010, 2013, 2014 Nayak, et al., 2010). Additionally, manganilmenite is found within the magnetite ore body of the NHO (Nayak and Meyer, 2017). Considering that manganilmenite is an indicator mineral for diamonds and ophiolites are newly recognized hosts for microdiamonds, the presence of manganilmenite in the magnetite suggests the potential for microdiamonds within the ophiolite rocks (Tompkins and Haggerty,1985, Kaminsky et al., 2001). The occurrence of native gold and gold-silver alloy highlights a new potential primary source of precious metals in the NHO (Ghose, 2014). In 2021 and 2022, two field visits were carried out, which led to the collection of several rock samples for future studies (Fig. 2).

Software program like VOSviewer, Gephi, Sci2 Tool, CitNetExplorer, Network Workbench, etc. is extensively employed in many kinds of intricate network analysis for scientific research, such as scientometrics, citation networks, and bibliometric analysis. This analysis includes journals, researchers, or individual articles that present vast maps clearly and understandably. With the recent advancements, CiteSpace software used for bibliographic analysis can be used to display the progression of knowledge in a study field in scientific metrology, data visualization, knowledge map construction, and application. To identify the cutting-edge research breakthroughs on ophiolite, this paper reviewed the Web of Science (WOS) research literature on ophiolite from 1994 to 2023. CiteSpace software is used to create scientific knowledge maps and to evaluate acupuncture and moxibustion publications. Chaomei Chen, a researcher at Drexel University in the United States, created CiteSpace to visualize and analyze scientific publications. It has been used in various domains since it can assess and anticipate the development trend of a specific study field through co-occurrence and co-citation analysis on a large number of relevant articles. CiteSpace accepts a wide range of data formats. It has a larger processing scale than other publication analysis software and can produce more thorough and understandable bibliometric analysis results. The bibliographic data identify a general profile of important nations and institutions, authors, and mainstream publications.

This paper aims to appraise the implications of the research in the field of ophiolite with special emphasis on Naga Hills Ophiolite.


Fig. 2: Field photograph of visible exposure of massive ultramafic rock outcrops (a, b, and c). Serpentinised peridotite showing a varied degree of alteration (d, e, and f).

## II. METHOD AND RESEARCH DATA

CiteSpace 6.3.R1 (64-bit) is a basic and free software (Fig.3). In addition to presenting the structure, rules, and distribution of scientific knowledge in terms of scientific metrology, data, and information visualization, it may be used to examine the potential knowledge in scientific investigations. It can quickly and accurately record the complex matrix of relationships between different components. Visual pictures are used to display abstract knowledge, which aids in increasing people's awareness. Two significant markers are CiteSpace's Centrality and Burst. The centrality graph function is used to identify and measure a term's importance as well as highlight a node's important points in purple-coloured circles. Burst is a phrase used to describe sudden additions of terms, publications, authors, journals, and other node-type citation information. CiteSpace analyses the data, threshold, and parameters that are initially established with precision to create a network graph that is easy to understand and has a high degree of centrality analysability.

The study also conducts thorough analysis, focusing primarily on the annual volume of publications, citations, authors, countries, journals, and other aspects. The quantity of academic papers is referred to as the quantity of publications. The quantity of publications on ophiolite in a given timespan reflects the field's condition, level, and speed of development; a study on author productivity and contribution might look into the narrative traits of the researchers in the area. The parameters in CiteSpace for co-occurrence and co-citation analysis of the authors are set, so that the number of publications and the degree of collaboration among authors based on the node and connection line can be assessed. The constitution of an institution that is at the cutting edge of a certain study field may be reflected in the research institutions' analytical findings. To ascertain the focuses and trends of the study on ophiolite, the often-used keywords, term bursts, and frequently cited publications are examined.

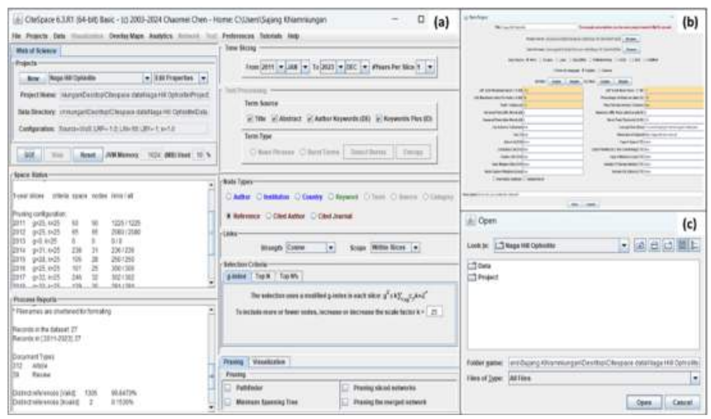


Fig. 3: (a) CiteSpace software's main window, (b) New project window, and (c) Project path window.

To assure the quality of the literature analysis, the present study verifies that the foreign literature gathered for this study is all from distinct journals, and the core databases are from the Web of Science (WOS) platform. The data available in Web of Science and methods used in the present study are divided into three parts, research articles published on Ophiolites on (i) global scale; (ii) in India, and (iii) NHO. The search string for the advanced retrieval from the WOS core collection database with the sub-formula [TS (Topic) = Ophiolite*; India ophiolite*; India*; Naga Hills Ophiolite*; Naga Ophiolite*], resulting in 8736, 468 and 27 research articles for ophiolite in Global, India, and NHO respectively.

The search covered publications from 1965-2023 (the date of the searched data is 21st June 2023). The research articles, papers, abstracts, etc. accessible in print formats are not included in this research. To prevent non-academic and invalid publications from impacting study results and to assure the accuracy and reliability of research in ophiolite, the search results from the Web of Science database are evaluated. To verify the validity of study outcomes, each item of data is first screened before being downloaded in full-record text format.

The analysis used CiteSpace 6.3.R1 (64 bit), examining 7763 global and 453 Indian publications from 1994 to 2023. Only 27 publications from 2011 to 2023 were analysed for NHO, since the first online publication on NHO was in 2011. Although the NHO is part of the records on ophiolites in India, it has been analysed separately as the main focus of the study. Based on the results of NHO literature, a preliminary fieldwork was carried out in parts of Noklak District, Nagaland, which forms the northeastern extension of the Naga Hills ophiolite belt. The area is located in Survey of India toposheet No.83 K/13, 0/1 and N/4 on a 1:50,000 scale, was considered as the base map after georeferenced and merged into a single map using QGIS 3.28.0. Google Earth Satellite Imagery of the area was studied for a better understanding of the terrain.

## III. RESULTS AND ANALYSIS

### *A. Publication Type Record*

There is a total of 8736 (Global ophiolite), 468 (ophiolites in India), and 27 (NHO) available resources about studies/research according to the Web of Science search. These resources are mostly comprising articles, editorial material, meeting abstracts, papers, reviews, abstracts, and other publication categories. It also includes the author, title, year of publication, number of pages, address, keywords, countries/territories, institutions, journals, citation, and discipline types included in the downloaded data information of text records in Web of Science. Even though the records were gathered between 1965 and 2023, network graph analysis is possible starting in 1994 using the basic free version of the CiteSpace software.

### *B. Quantitative analysis of yearly publications*

Considering the global resources, the very first publication concerning the study of ophiolite was discovered in the database in 1967, with two publications available in that year while the first publication on the study of ophiolites in India was in 1986, with only one publication. In 2020, there were about 467 publications, and the field of study on ophiolite globally (Fig. 4a) was very active. The ophiolites in India studies were active in 2022 with 42 publications (Fig. 4b). The first publication concerning the study on NHO was discovered in the database in 2011, with only one publication available in that year. Over 10 years, from 2011 to 2021, the number of publications per year was constant at less than 5. Since 2021, NHO research has had increased activity, with the number of publications rising quickly from 2 in 2021 to 7 in 2022 (Fig. 4c). The number of publications varied but overall, there was an upward trend with an increasing publication each year. It is unfortunate that the important pioneering research is only available in print and has not yet been posted online. The pioneering investigations could not be evaluated in the current study.

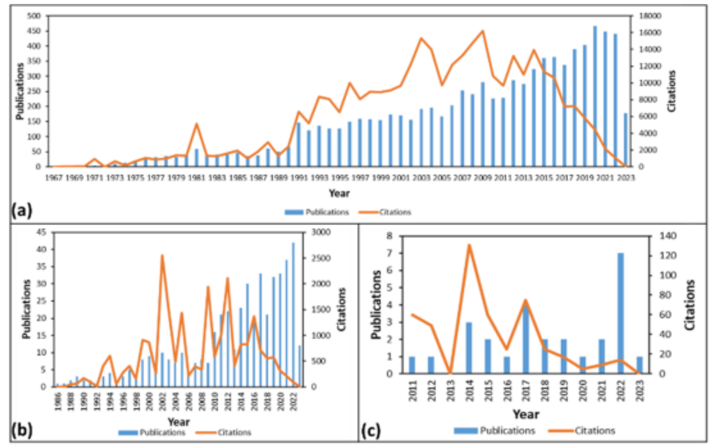


Fig. 4: Distribution of yearly publication of studies of ophiolites on (a) Global (1967-2023), (b)India (1986-2023), and (c) NHO (2011-2023) available in Web of Science.

### *C. Co-Citation Analysis of Publications*

This study shows that despite not receiving many citations, Dilek, Y. (2011) is the most often referenced work, with a large burst (Table I, Fig. 5a) Dilek, Y. publication on "Ophiolite genesis and global tectonics: Geochemical and tectonic fingerprinting of ancient oceanic lithosphere" provide a review of theories and hypotheses regarding the origin of ophiolites, along with a new classification and geochemical signatures resulting from variations in petrological, geochemical, and tectonic processes during formation across different geodynamic settings. Ophiolites, according to the authors, are suites of ultramafic to felsic rocks that are chronologically and geographically correlated and are linked to distinct melting episodes and processes of magmatic differentiation in certain tectonic contexts. The analysis of ophiolites in India shows that Hebert, R. (2012) is the most often referenced work, with high corresponding centrality, and burst (Table I, Fig. 5b). Hebert, R. publication on "The Indus–Yarlung Zangbo ophiolites from Nanga Parbat to Namche Barwa syntaxes, southern Tibet: First synthesis of petrology, geochemistry, and geochronology with incidences on geodynamic reconstructions of Neo-Tethys" discusses about the evolution of the Yarlung Zangbo Suture Zone and its genesis where the ophiolites are formed in a nascent arc, the older units of ophiolite sequence are generated in the subduction zone, obduction of ophiolite proceed with related retrograde metamorphism and final closing with marine sediments dated 34 Ma. Research on Naga Hills Ophiolite shows that Singh, A. K. (2017) is the most often referenced work with the largest corresponding nodes in the graph and moderately high corresponding centrality (Table I, Fig. 5c). Singh, A. K. publication on "New U–Pb zircon ages of plagiogranites from the Nagaland–Manipur Ophiolites, Indo-Myanmar Orogenic Belt, NE India" report that the discovered samples are of oceanic plagiogranites with trondhjemitic composition, metaluminous affinities and derived from a depleted mantle source. This paper also discusses the existence of subduction components in the source region and shows that the ophiolites in the Indus-Yarlung-Tsangpo Suture are geochemically similar to Neo-Tethyan ophiolites. Khogenkumar, S., (2021) has a large burst despite having a lower citation frequency and centrality. This implies that the analysis produced noteworthy findings by reviewing data from the literature and contrasting it with the most recent geochemical data. It drew a lot of interest as the study attempts to shed new light on the prolonged discussion around the geodynamic evolution of the Naga-Manipur Ophiolite; as a result, it can be used to guide future research trends.

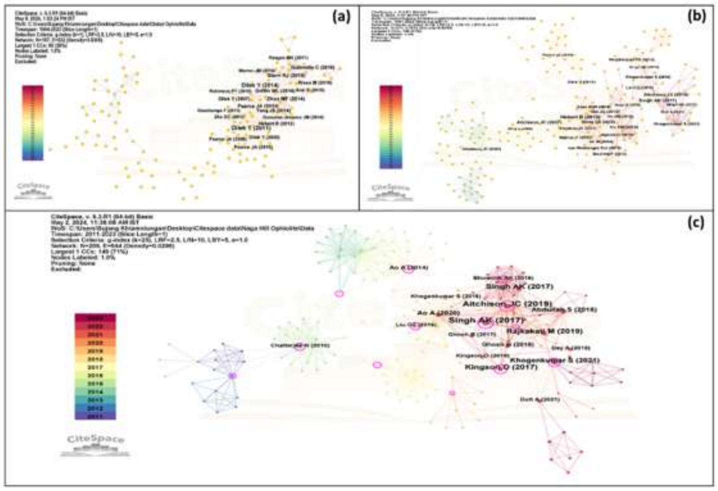

Fig. 5: (a) & (b) Network analysis of highly cited publications of ophiolite during 1994-2023 (Global and India) and (c) 2011-2023 (NHO).

Table I: Characteristics of highly cited research publications on ophiolite.

| No. | | Publications | Count | Centrality | Burst |
|---|---|---|---|---|---|
| 1 | Global | Dilek, Y., (2011), *Geological Society of America Bulletin*, V123, P387, doi:10.1130/B30446.1 | 185 | 0.39 | 80.65 |
| 2 | Global | Pearce, J. A., (2014), *Elements*, V10, P101, doi:10.2113/gselements.10.2.101 | 85 | 0.32 | 35.9 |
| 3 | Global | Zhou, M. F., (2014), *Gondwana Research*, V26, P262, doi:10.1016/j.gr.2013.12.011 | 83 | 0.05 | 37.59 |
| 4 | Global | Stern, R. J., (2018), *Tectonophysics*, V746, P173, doi:10.1016/j.tecto.2017.10.014 | 79 | 0.33 | 31.81 |
| 5 | Global | Guilmette, C., (2018), *Nature Geoscience*, V11, P688, doi:10.1038/s41561-018-0209-2 | 77 | 0.01 | 30.98 |
| 6 | India | Hebert, R., (2012), *Gondwana Research*, V22, P377, doi:10.1016/j.gr.2011.10.013 | 28 | 0.39 | 10.39 |
| 7 | India | Singh, A. K., (2017), *Journal of Geological Society London,* V174, P170, doi:10.1144/jgs2016-048 | 21 | 0.2 | 5.53 |
| 8 | India | Aitchison, J. C., (2007), *Journal of Geophysical Research-Solid Earth*, V112, P0, doi:10.1029/2006JB004706 | 19 | 0.43 | 9.99 |
| 9 | | Hu, X. M., (2015), *Geology*, V43, P859, doi:10.1130/G36872.1 | 15 | 0.17 | 7.31 |
| 10 | | Dai, J. G., (2013), *Lithos*, V172, P1, doi:10.1016/j.lithos.2013.03.011 | 14 | 0.3 | 2.81 |
| 11 | Naga Hills Ophiolite | Singh, A. K., (2017), *Journal of Geological Society London*, V174, P170, doi:10.1144/jgs2016-048 | 11 | 0.18 | 1.70 |
| 12 | Naga Hills Ophiolite | Aitchison, J. C., (2019), *Tectonics*, V38, P1718, doi:10.1029/2018TC005049 | 10 | 0.18 | 1.84 |
| 13 | Naga Hills Ophiolite | Kingson, O., (2017), *Chemical Geology*, V460, P117, doi:10.1016/j.chemgeo.2017.04.021 | 8 | 0.11 | 1.32 |
| 14 | Naga Hills Ophiolite | Rajkakati, M., (2019), *Lithos*, V346, P0, doi:10.1016/j.lithos.2019.105166 | 8 | 0.05 | 2.03 |
| 15 | Naga Hills Ophiolite | Khogenkumar, S., (2021), *Geological Journal*, V56, P1773, doi:10.1002/gj.4030 | 7 | 0.15 | 2.44 |

### *D. Co-Occurrence and Co-Citation Analysis of Authors*

The findings of the co-occurrence analysis from 1994 to 2023 (Global and India ophiolites) and 2011 to 2023 (NHO) show that there is some degree of author cooperation. The authors who published more than 50 research articles on ophiolites on a global scale are Arai, S. and Yang, J., (Table II, Fig. 6a). Santosh, M., and Ghosh, B., are the authors who have published a comparatively large number of research articles on ophiolites in India (Table II; Fig. 6b). The top authors who have published 5 and 4 research articles with special reference to NHO are Singh, A. K., and Ao, A., followed by Imtisunep, S., Dutt, A., and Chaubey, M., with 3 publications each. Ao, A., and Satyanarayanan, M., are ranked following the centrality graph, and the node is marked in purple-coloured circle as given in Fig.6c (Table II).

Table II: Information of productive authors who published research articles on ophiolite.

| No. | | Author | Count | Centrality |
|---|---|---|---|---|
| 1 | Global | Arai, S. | 82 | 0 |
| 2 | Global | Yang, J. | 65 | 0.02 |
| 3 | Global | Santosh, M. | 47 | 0 |
| 4 | Global | Dilek, Y. | 42 | 0 |
| 5 | Global | Xiao, W. | 29 | 0 |
| 6 | India | Santosh, M. | 19 | 0.01 |
| 7 | India | Ghosh, B. | 13 | 0 |
| 8 | India | Singh, A. K. | 7 | 0.02 |
| 9 | India | Searle, M. P. | 6 | 0 |
| 10 | India | Aitchison, J. C. | 6 | 0 |
| 11 | Naga Hills ophiolite | Singh, A. K. | 5 | 0.06 |
| 12 | Naga Hills ophiolite | Ao, A. | 4 | 0.16 |
| 13 | Naga Hills ophiolite | Imtisunep, S. | 3 | 0.02 |
| 14 | Naga Hills ophiolite | Dutt, A. | 3 | 0.02 |
| 15 | Naga Hills ophiolite | Chaubey, M. | 3 | 0.02 |

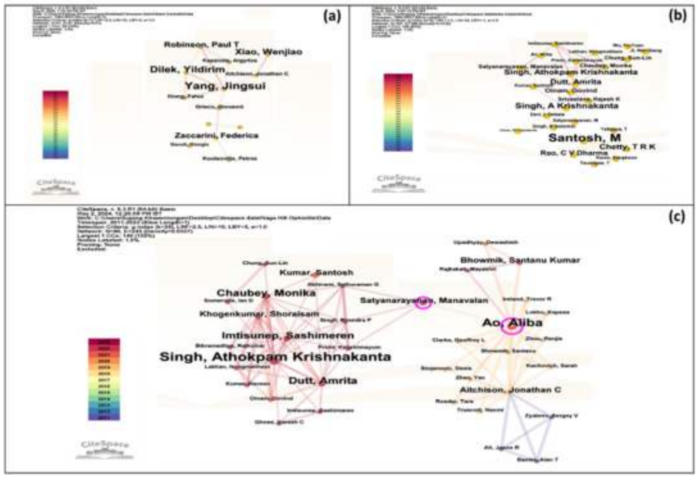

Fig.6: The co-occurrence of productive authors of ophiolite on (a) Global, (b) India, and (c) NHO.

The co-citation analysis results from 1994 to 2023 (Global and India) and 2011 to 2023 (NHO), the top authors with the highest frequency of citations on ophiolites in global scale are Kelemen, P. B., Boudier, F., Yang, J. S., Saccani, E. and Robinson, P. T. and on ophiolites in India are Aitchison, J. C., Yin, A., Arai, S., Singh, A. K., and Ghosh, B. The top five authors with the highest frequency of citations on NHO are Baxter, A. T., Bhowmik, S. K., Khogenkumar, S., Imtisunep, S., and Ningthoujam, P. S., and those with a relatively high centrality are Bhowmik, S. K., and Baxter, A. T. The analysis reveals that authors, like Baxter, A. T., have a comparatively small number of publications, a high frequency of citations, and a high centrality, all of which suggest that the author's study on NHO has a comparatively great influence and a high level of attention. Additionally, certain authors like Khogenkumar, S., and Baxter, A.T., have strong bursts, and their writings receive a lot of attention for a while (Table III). Thus, it is not sufficient to solely base an author's influence on the study of ophiolite on the number of publications.

Table III: Information of highly cited authors who published research articles on ophiolite.

| No. | | Author | Count | Centrality | Burst | Publications |
|---|---|---|---|---|---|---|
| 1 | Global | Kelemen, P. B. | 1058 | 0.04 | 3.06 | Kelemen, P. B., (1995), *Nature*, V375, P747 |
| 2 | | Boudier, F. | 685 | 0.07 | 4.95 | Boudier, F, (1995), *Journal of Petrology*, V36, P777 |
| 3 | | Yang, J. S. | 377 | 0.02 | 1.30 | Yang, J. S., (2014), *Elements*, V10, P127 |
| 4 | | Saccani, E. | 301 | 0.01 | 36.88 | Saccani, E., (2015,) *Geoscience Frontiers*, V6, P481 |
| 5 | | Robinson, P. T. | 294 | 0.01 | 45.74 | Robinson, P. T., (2004), *Geological Society Special Publications*, V226, P247 |
| 6 | India | Aitchison, J. C. | 124 | 0.26 | 3.75 | Aitchison, J. C., (2002), *Journal of Asian Earth Science*, V21, P251 |
| 7 | | Yin, A. | 96 | 0.22 | 2.1 | Yin, A., (2000), *Annual Review of Earth and Planetary Sciences*, V28, P211 |
| 8 | | Arai, S. | 56 | 0.03 | 2.11 | Arai, S., (2011), *Island Arc*, V20, P125 |
| 9 | | Singh, A. K. | 42 | 0.05 | 4.93 | Singh, A. K., (2017), *Geological Journal*, V52, P415 |
| 10 | | Ghosh, B. | 36 | 0.04 | 8.54 | Ghosh, B., (2014), *Ore Geology Review*, V56, P199 |
| 11 | Naga Hills Ophiolite | Baxter, A. T. | 16 | 0.01 | 1.05 | Baxter, A. T., (2011), *Gondwana Research*, V20, P638 |
| 12 | | Bhowmik, S. K. | 13 | 0.02 | 0.72 | Bhowmik, S. K., (2014), *Journal of Petrology*, V55, P585, |
| 13 | | Khogenkumar, S. | 8 | 0 | 1.98 | Khogenkumar, S., (2021), *Geological Journal*, V56, P1773 |
| 14 | | Imtisunep, S. | 2 | 0 | 0.63 | Imtisunep, S., (2022), *Geological Journal*, V57, P782 |
| 15 | | Ningthoujam, P. S. | 1 | 0 | 0.62 | Ningthoujam, P. S., (2012), *Journal of Asian Earth Science*, V50, P128 |

### E. *Quantitative Analysis of Different Countries and Research Organisations*

Conferring to the analysis's findings of global ophiolites, Peoples Republic of China is the country with the most publications, followed by the USA, France, Germany, and England. Considering the available publications on ophiolites in India, the analysis's findings have India as the country with the most publications, followed by Peoples Republic of China, USA, Japan, and Australia. All of the participating countries have a tight working relationship. The top countries with the highest node centrality on ophiolites on a global scale are the USA, France and India are India and Peoples Republic of China, and Germany. These countries' publications have a fairly large global impact (Table IV; Fig. 7a, 7b). The analysis's findings on NHO, India is the country with the most publications, followed by Australia, Germany, Japan, and Peoples Republic of China. It appears that India and Australia are the countries with the most nodes and publications with overall indicated by the purple-coloured circle (Fig. 7c). In the knowledge graph, China has fewer publications but strong node centrality, indicating that the publications have a significant impact. Australia has the strongest bursts, indicating that their research accomplishments have attracted particularly significant attention in the year 2019. The top four countries with the highest node centrality are India, Peoples Republic of China, Australia, and Germany. (Table IV, Fig. 7c).

Table IV: Contribution of research publications of the top productive countries on ophiolite.

| No. | | Country | Count | R (%) | Centrality |
|---|---|---|---|---|---|
| 1 | Global | Peoples R China | 1717 | 1 (15.77) | 0.06 |
| 2 | | USA | 1478 | 2 (13.80) | 0.14 |
| 3 | | France | 753 | 3 (7.00) | 0.13 |
| 4 | | Germany | 695 | 4 (6.43) | 0.05 |
| 5 | | England | 647 | 5 (6.06) | 0.08 |
| 6 | India | India | 231 | 1 (29.96) | 0.73 |
| 7 | | Peoples R China | 133 | 2 (17.25) | 0.32 |
| 8 | | USA | 63 | 3 (8.56) | 0.10 |
| 9 | | Japan | 43 | 4 (5.58) | 0.03 |
| 10 | | Australia | 40 | 5 (5.19) | 0.04 |
| 11 | Naga Hills Ophiolite | India | 25 | 1 (58.14) | 1.60 |
| 12 | | Australia | 3 | 2 (6.98) | 0.08 |
| 13 | | Germany | 2 | 3 (4.65) | 0.04 |
| 14 | | Japan | 2 | 3 (4.65) | 0 |
| 15 | | Peoples R China | 2 | 3 (4.65) | 0.31 |

*R (%) Rank and the percentage of total publication

The most relevant organizational data in the ophiolite field was found by the institutional collaboration analysis. The time span parameter was set to 1994 to 2023 (Global and India) and 2011-2023 (NHO), the year per slice to 1. The institution was chosen in the network configuration function area, and the title, abstract, author, and keywords were set in the text processing function area in the selection criteria. These parameters were used to analyze and classify the institutions. The literature was gathered in the WOS database; the network visualization map (Fig. 9) was generated. This indicates that the seven institutions of studies on ophiolites on global and Indian scales had published more than 300 and 20 articles respectively. Chinese Academy of Sciences is the most productive institution in terms of publications from 1994 to 2023, accounting for more than 30% of the total publications (Figs. 8a, 9a, 9b). The four institutions namely the Department of Science & Technology (India), Wadia Institute of Himalayan Geology (WIHG), Indian Institute of Technology System (IIT System), Indian Institute of Technology (IIT)-Kharagpur and Council of Scientific & Industrial Research (CSIR)-India have published more than 5 articles on studies of NHO (Fig. 8b). The Department of Science & Technology and Wadia Institute of Himalayan Geology are the most productive institutions in terms of publications from 2011 to 2023, accounting for more than 40% of the total publications. The strongest centralization among them is found at the Department of Science & Technology, Wadia Institute of Himalayan Geology, and Council of Scientific & Industrial Research (CSIR) India, demonstrating their prominence in the study of NHO. The strongest bursts come from Banaras Hindu University, Nagaland University, and the Ministry of Earth Sciences, showing that their research on NHO during a particular time period of the study gained unexpected attention (Fig. 8b, 9c).

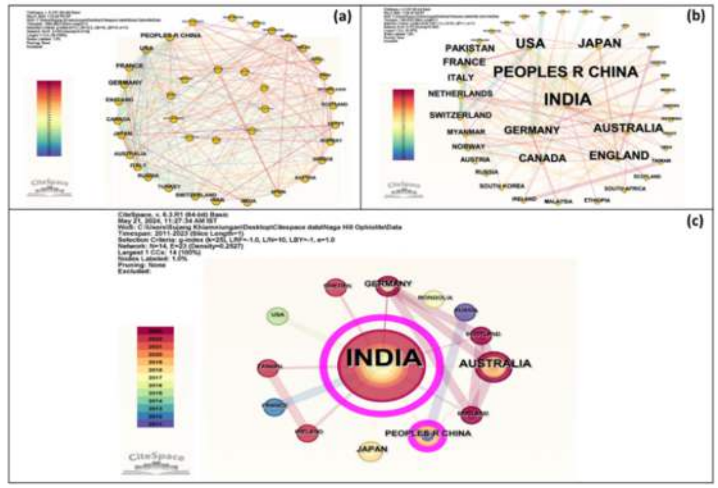


Fig. 7: The cooperation network of the productive countries that published research articles on ophiolite (a) Global, (b) India, and (c) NHO.

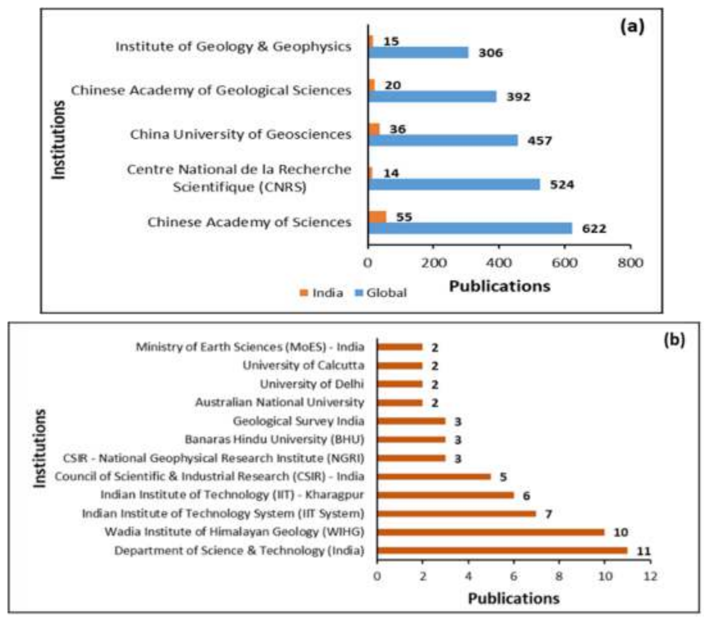


Fig. 8: The total publications of the most productive institutions of ophiolite on (a) Global and India and (b) Naga Hills Ophiolite.

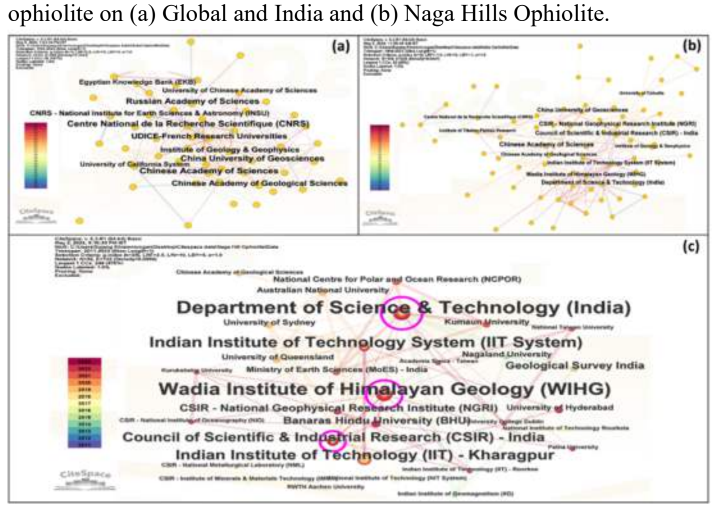


Fig. 9: The cooperation network of the most productive institutions that published research articles on ophiolite on (a) Global, (b) India, and (c) Naga Hills ophiolite.

### F. *Quantitative Analysis of the Main Discipline Types and Journals*

The term 'discipline' refers to an academic categorization that designates a particular area of science or branch of science. According to Web of Science's classification of disciplines on ophiolite on a Global and Indian scale, there are seven disciplines with more than 100 publications and six disciplines with more than 10 publications respectively. Geosciences Multidisciplinary is the most productive key discipline among them, accounting for 3285 (Global) and 254 (India) relevant publications. Geochemistry Geophysics, Mineralogy, and Geology are the next most productive key disciplines (Fig. 10a). Web of Science's classification of disciplines in NHO, there are five disciplines in the study of NHO. Geosciences Multidisciplinary is the most productive key discipline among them, accounting for 15 relevant publications, or 55.556% of all publications. Multidisciplinary Sciences, and Geochemistry, Geophysics are the next most productive key disciplines, with 18.519% and 14.815% of publications each. Geology and Mineralogy are the least productive key disciplines, with 11.111% and 7.407% of publications each (Fig. 10b).

Geosciences Multidisciplinary, Multidisciplinary Sciences, Geochemistry and Geophysics are key disciplines in terms of publications pertinent to the study of NHO, while Geology and Mineralogy are the least disciplines. This suggests that the study of NHO will be extensively applied in the future, with strong interaction with various disciplines. For instance, the study on NHO conducted by geosciences and geology is based on findings from studies conducted in the fields of geosciences multidisciplinary and geochemistry geophysics as well as geology and mineralogy. Extending and exchanging their academic expertise on the study of NHO suggests that the new disciplines could take advantage of the technical benefits now held by other disciplines in these subjects, so promoting their development. Additionally, they might leverage cutting-edge technologies to solve their main issues and be crucial to their growth and penetration.

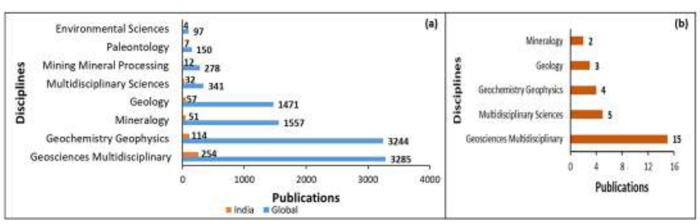


Fig. 10: Publications of the most productive categories of ophiolite on (a) Global and India and (b) Naga Hills Ophiolite.

Table V: Distribution of output in Key journals on ophiolite.

| No. | | Journal | Count | IF Impact Factor (2023) | Centrality |
|---|---|---|---|---|---|
| 1 | Global | Earth Planetary Science Letters | 5801 | 5.785 | 0.04 |
| 2 | | Geology | 5078 | 6.32 | 0.02 |
| 3 | | Tectonophysics | 4760 | 3.66 | 0.03 |
| 4 | | Contributions to Mineralogy and Petrology | 4681 | 4.107 | 0.05 |
| 5 | | Chemical Geology | 4487 | 4.685 | 0.03 |
| 6 | India | Earth Planetary Science Letters | 377 | 5.785 | 0.05 |
| 7 | | Tectonophysics | 353 | 3.66 | 0.02 |
| 8 | | Geology | 347 | 6.32 | 0.05 |
| 9 | | Journal of Asian Earth Sciences | 328 | 3.374 | 0.06 |
| 10 | | Geological Society of America Bulletin | 295 | 5.41 | 0.07 |
| 11 | Naga Hills Ophiolite | Geology | 23 | 6.32 | 0.2 |
| 12 | | Lithos | 23 | 3.56 | 0.1 |
| 13 | | Contributions to Mineralogy and Petrology | 23 | 4.107 | 0.2 |
| 14 | | Journal of Asian Earth Sciences | 23 | 3.374 | 0.2 |
| 15 | | Chemical Geology | 22 | 4.685 | 0.23 |

In some ways, the distribution of journals reflects how important a particular discipline's publications are. It is one of the most important indicators for assessing the discipline's level of development. Web of Science's search report on ophiolite globally, two journals had over 5000 publications between 1994 and 2023, while seven journals had 4000 or more. Among these, Earth Planetary Science Letters, Geology, Tectonophysics, Contributions to Mineralogy and Petrology, and Chemical Geology rank at the top. Research articles on India ophiolite, four journals had more than 300 publications between 1994 and 2023, while twelve journals had 200 or more. Among these, Earth Planetary Science Letters, Tectonophysics, Geology, Journal of Asian Earth Sciences, and Geological Society of American Bulletin rank at the top. Web of Science's search report on NHO, seven journals had more than 20 publications between 2011 and 2023, while six journals had 15 or more. Among these, Geology, Lithos, Contributions to Mineralogy and Petrology, Journal of Asian Earth Sciences, and Chemical Geology rank at the top. The analysis shows that Chemical Geology has the highest centrality (Table V).

The majority of publications come from different types of journals, which highlights the diversity of publishing distribution, the broad scope of study interests, as well as the impact of cross-disciplinary penetration. Additionally, the influence factor of the journal is not directly correlated with the volume of publications and the frequency of citations in the field of study on NHO, so the influence of the journal in the study field cannot be determined solely by the influence factor.

### G. *Analysis of Keywords*

Keywords are employed to condense the article's content; keyword analytics can identify the research topics over time. According to studies of ophiolite, the dynamic evolution graph of keywords shows that oceanic crust impact first appeared in 1998 and then again in 2015, showing a shift in the study's emphasis from ophiolite petrography attributes to geochemistry (Fig. 11a). According to the findings, "subduction on initiation" has a strong burst with 53.94, followed by "Zircon U Pb" with 36.09 and "trace element" with 27.48. In addition to the search phrases ophiolite and India plate also rank highly in this subject. The dynamic evolution graph of keywords shows that India Asia collision impact first appeared in 2007 and then again in 2015, showing a shift in the study's emphasis from ophiolite petrography attributes to the structural geology (Fig. 11b). According to the findings, "subduction initiation" with 7.22 has a strong burst, followed by "India Asia collision" with 6.49. Thus, there is a lot of interest in structural geology and tectonic collision. The dynamic evolution graph of keywords shows that abyssal peridotite impact first appeared in 2012 and then again in 2017, showing a shift in the study's importance from ophiolite petrography attributes to petrogenesis. "Midocean ridge" has a strong burst with 2.27, followed by "hills ophiolite" with 2 and "Myanmar orogenic belt" with 1.53. This implies that there is a lot of interest in geochemistry and the Myanmar orogenic belt (Fig. 11c).

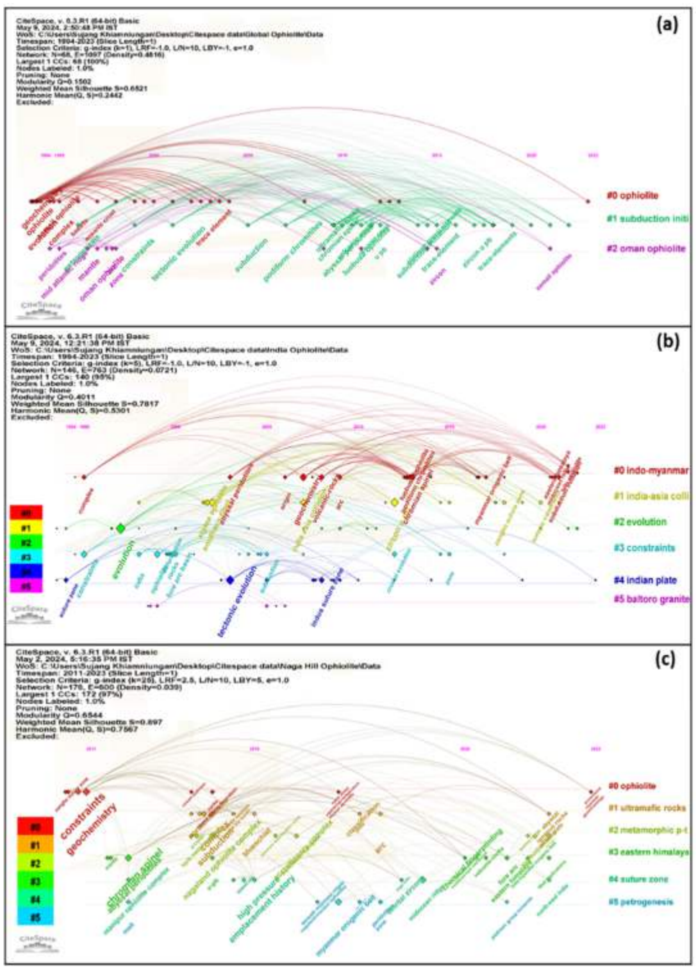


Fig. 11: The TimeZone of keywords of ophiolite on (a) Global, (b) India, and (c) Naga Hills Ophiolite.

Table VI: Characteristics by year of high-frequency keywords of ophiolite.

| No. | | Keywords | Frequency | Centrality | Year | Burst |
|---|---|---|---|---|---|---|
| 1 | Global | Evolution | 1207 | 0.13 | 1994 | 1.93 |
| 2 | | Ophiolite | 858 | 0.08 | 1994 | 2.98 |
| 3 | | Geochemistry | 846 | 0.26 | 1994 | |
| 4 | | Tectonic Evolution | 688 | 0.18 | 2001 | 1.18 |
| 5 | | Origin | 659 | 0.22 | 1994 | 6.78 |
| 6 | India | Evolution | 68 | 0.59 | 1997 | 2.1 |
| 7 | | Tectonic Evolution | 55 | 0.25 | 2003 | 4.28 |
| 8 | | Zircon U Pb | 45 | 0.1 | 2012 | 4.17 |
| 9 | | Southern Tibet | 36 | 0.1 | 2002 | |
| 10 | | Geochemistry | 35 | 0.13 | 2007 | 3.37 |
| 11 | Naga Hills Ophiolite | Geochemistry | 9 | 0.4 | 2011 | 0.73 |
| 12 | | Myanmar Orogenic Belt | 8 | 0.05 | 2017 | 1.53 |
| 13 | | Chromian Spinel | 7 | 0.42 | 2012 | 1.20 |
| 14 | | Abyssal Peridotites | 7 | 0.09 | 2012 | 0.83 |
| 15 | | Midocean Ridge | 7 | 0.02 | 2019 | 2.27 |

## CONCLUSION

Ophiolites originate in various tectonic conditions during the Wilson cycle evolution of ancient ocean basins, from rift-drift and seafloor spreading stages to subduction initiation and closure phases. They vary in their internal structure, geochemical composition, and emplacement methods. As the ophiolite complexes age, there seems to be a general tendency toward greater subduction-signal. The most conservative explanation for surface tectonics throughout almost 4 billion years of Earth's history is that there were counterbalanced by at least 50% MORB-like sequences throughout the Archean, indicating modern-like plate tectonic processes (Furnes, H. et al., 2014). Determining the precise tectonic setting of ophiolite production and, consequently, the procedures by which these oceanic rocks were obducted onto continental edges can be facilitated by characterizing ophiolites (Dilek, Y. and Furnes, H. 2011). The idea of ophiolite will continue to develop and contribute significantly to our knowledge of Earth's past (Dilek, Y. 2003).

With special reference to Naga Hills Ophiolite, this study uses bibliometric approaches to examine and assess the current state of ophiolite research, as well as its trends and focus. The data used for mapping the network graph of ophiolite in India is a part of the global data, similarly, the NHO data is also a part of the India data. CiteSpace is used to determine the publications, authors, countries, institutions, disciplines, journals, and other relevant data. It shows that, since the beginning of ophiolite research in 1967, this field has developed steadily and slowly from 1973 to 1990, and in 1991, interest in this subject started to grow quickly.

Thus far, NHO's research findings have heightened yearly. Singh, A. K., Aitchison, J. C., Bhowmik, S. K., Ao, A., et al. have all made very significant and influential contributions to the field of study on NHO. China and the USA are among the most productive in terms of total number of publications. India, Australia, China, and other nations collaborate closely, according to analysis of NHO. The Chinese Academy of Sciences is one of the most significant institutions in this field, publishing the most publications on ophiolite research globally, but the Department of Science & Technology (India) holds the leading position when it comes to NHO. The pertinent research on NHO mostly focuses on the disciplines of Geosciences Multidisciplinary, Geochemistry Geophysics, Mineralogy, Geology, and other disciplines with strong interdisciplinary characteristics. The major journals with the most notable research accomplishments, the highest number of publications, and the strongest fluency are the International Journal of Geology, Lithos, Contributions to Mineralogy and Petrology, and Earth Planetary Science Letter. The subduction initiation and evolution of NHO are a study focus, based on the analysis of relevant study markers. The research on NHO has been aided by studies on the Mid Oceanic Ridge and the chrome spinel of ophiolite in Nagaland.

A preliminary approach was done through a field study and few samples were collected across a localized portion of the NHO unit. A new map of NHO was generated from QGIS 3.28.0 using the Geological Survey of India, 1974, 1975, 1980, 1982 and toposheet No.83 K/13, 0/1, N/4 on 1:50,000 scale as base map. The new map generated (Fig. 1c) displays ultramafic rocks in the regions previously identified as Disang Formation and Naga Metamorphics. During the field visits, traverses along and across the ophiolite unit were conducted, including both road and footpath routes.

The current study has certain limitations, yet it offers many relevant details about ophiolite, notably NHO. First, due to the limitation of CiteSpace software, research articles that are available in print are not included in this study for analysis. Second, the results will become outdated in the future as they are based on research articles from 1994 to 2023. The primary goal of this study is to evaluate the literature using a novel quantitative approach. We plan to conduct additional research in this area by refining our search parameters and staying up to date with upcoming papers.

## Acknowledgment

The authors acknowledge CiteSpace and QGIS software platforms for making them freely available for processing. The authors thank IGNOU for its facilities and the Director, School of Sciences for encouragement. Prof. Benidhar Deshmukh of the School of Sciences, IGNOU, is also acknowledged, for his continuous support and encouragement while preparing this research paper.

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