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Potential Geosites Evaluation: Case Studies of the Mineral Paradise @ Mineral Occurrences of Shantaung-U and Shwe- Thar- Lyaung Hills, Kyaukse District, Mandalay Region; Pedagogical Implication Geoheritage and Geoco nservation on Minerals and Rocks

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Abstract

Geosites are sites of scientific interest based on geology or geomorphology that can serve various purposes, such as future research, conservation, education, tourism or sustainable development of a certain area (Lena and Carbone, 2016). This study evaluates the geosites of Shantaung-U and Shwe-Thar-Lyaung Hills, located in the Kyaukse District, Mandalay Region, renowned for their geological and mineralogical significance. These areas, often referred to as "Mineralogist's Paradise," host a rich diversity of metamorphic and igneous rocks. In these areas, biotite-hornblende gneiss, various types of marbles including andalusite marble, various types of schists including sillimanite schists, quartzite, calc-silicate rocks, phyllites and some pegmatites are well exposed. Metamorphic minerals such as garnet, tremolite, actinolite, diopside, forsterite, phlogopite, chiastolite, spinel, tourmaline and aluminosilicate polymorph minerals such as andalusite, sillimanite and kyanite are found in this area. Among these metamorphic minerals, especially aluminosilicate polymorphs, kyanite is considered as a rare gem mineral compared to other minerals and their occurrences are limited in Myanmar especially found in at least 3 places namely Kathar-Gangaw range in Kachin State, Min Wun range and Shantaung-U range in Mandalay Region. Kyanite is unusual mineral formed under high-pressure, low-temperature conditions in regional metamorphism of pelitic rocks. It can help phase diagrams, stability and T-P conditions in metamorphic environments. While these Mineralogist’s Paradise may not hold much significance for layman, this site is invaluable for geological research, particularly for postgraduate studies and as a training ground for undergraduate students. Mineralogist’s Paradise thus serves as pedagogical use, a versatile mineral in geological education, helping illustrate concepts in mineralogy and petrology. By promoting this Mineralogist’s Paradise as a part of geosite, it will conserve geological, mineralogical heritage as well as geodiversity, geoheritage which leads to the sustainable development of geopark and geo-tourism, the local economy and society.

Keywords: Geosite, Kyanite, Pedagogical use, regional metamorphism, Training ground

မန္တလေးတိုင်းဒေသကြီး၊ ကျောက်ဆည်ခရိုင်၊ ရှမ်းတောင်ဦးဒေသနှင့် ရွှေသာလျောင်း တောင်တန်းဝန်းကျင်ဒေသများရှိ ကျောက်များနှင့် တွင်းထွက်များအား ပညာသင်ကြားရေး နယ်ပယ်၊ ဘူမိအမွေအနှစ်နှင့် ဘူမိထိန်းသိမ်းကာကွယ်ရေးတို့ အတွက် ဘူမိသိပ္ပံဆိုင်ရာ စိတ်ဝင်စားဖွယ် နေရာ (Geosite) တစ်ခုအဖြစ်လေ့လာ ဆန်းစစ် ရွေးချယ်သတ်မှတ်ခြင်း

လင်းလက်မိုးပြည့်အောင်၊ ဘူမိဗေဒလက်ထောက်-၂
ဘူမိဗေဒလေ့လာရေးနှင့် ဓာတ်သတ္တုရှာဖွေရေးဦးစီးဌာန

စာတမ်းအကျဉ်း

ဘူမိသိပ္ပံဆိုင်ရာစိတ်ဝင်စားဖွယ်နေရာ(Geosites)များသည် ဘူမိဗေဒနှင့် ဘူမိရုပ်သွင်ဆိုင်ရာ ထူးခြားမှုများကိုအခြေခံကာ ကမ္ဘာမြေကြီး၏ ဆင့်ကဲပြောင်းလဲမှုဖြစ်စဉ် မိုင်းများကို သိရှိ နားလည် နိုင်ရုံသာမဟုတ်ဘဲ ပညာရပ်ဆိုင်ရာသုတေသန လေ့လာမှုများ၊ သဘာဝပတ်ဝန်းကျင်ဆိုင်ရာ ထိန်းသိမ်းစောင့်ရှောက်မှုများနှင့် ခရီးသွားလုပ်ငန်းများ ဖွံ့ဖြိုးတိုးတက်ရေးများအတွက်ပါ များစွာ အရေးပါသည့်နေရာ များပင်ဖြစ်ပါသည်။ ယခုစာတမ်းတွင် မန္တလေးတိုင်းဒေသကြီး၊ ကျောက်ဆည် ခရိုင်အတွင်းမှ ရှမ်းတောင်ဦးဒေသနှင့်ရွှေသာလျောင်း တောင်တန်းဝန်းကျင်ဒေသများတွင် ဖြစ်ထွန်း တည်ရှိနေသော တွင်းထွက်ဘူမိဗေဒဆိုင်ရာထူးခြားမှုများကို ဘူမိသိပ္ပံဆိုင်ရာ စိတ်ဝင်စားဖွယ် နေရာ များအဖြစ် ထိန်းသိမ်းမှတ်တမ်းတင် ထားရှိနိုင်ရေးအတွက် လေ့လာ ဆန်းစစ် အကဲဖြတ်မှု များကို ရေးသားတင်ပြထားခြင်းဖြစ်ပါသည်။ ဤဒေသသည် မီးသင့်ကျောက်များနှင့် အသွင်ပြောင်း ကျောက်များ၏ ဘူမိနယ်ပယ်ဖြစ်ထွန်းမှု စုံလင်လှသဖြင့် တွင်းထွက်ကျောက် ပညာရပ်အား လေ့လာသူများအတွက် တွင်းထွက်စုံလင်သည့်တွင်းထွက်ဘုံ(ပါရာဒိုက်)ဟု ပင်ပြောစမှတ်တွင်သည့် နေရာလည်းဖြစ်ပါသည်။ ထို့ပြင်လချေးညှိကြွယ် လိပ်သည်းကျောက်များ၊ အန်ဒါလူးဆိုက် တွင်းထွက်အပါအဝင် စကျင်ကျောက်မျိုးကွဲများ၊ ဆေးလ်မနိုက်၊ ကွာဇိုက်၊ ကာ့ဆီလီကိတ်များ၊ ဖီးလိုက်နှင့် ပက်ဂမာတိုက်စသည့် ကျောက်အမျိုးမျိုးတို့ ကောင်းစွာ ပေါ်ထွက် လျက်ရှိပါသည်။ အသွင်ပြောင်းကျောက်များဖြစ်သော ဥဒေါင်၊ အက်တီနိုလိုက်၊ မိုးကုတ်မြေ၊ ဖော်စတာရိုက်၊ ဖလိုက် ပိုက်၊ ချက်စတိုလိုက်၊ အည့ံပန်း၊ တိုမလင်းနှင့် အလူမီနိုဆီလီကိတ် မူကွဲ တွင်းထွက်များဖြစ်သော အန်ဒါလူးဆိုက်၊ ဆေးလ်မနိုက်၊ မိုးညှင်းနီလာ ကျောက်မျက်များလည်း ဖြစ်ထွန်းပါသည်။ ထူးခြား သည်မှာ မိုးညှင်း နီလာကျောက်မျက် တွင်းထွက်များကို ယခုရှမ်း တောင်ဦး ဒေသအပါအဝင် မန္တလေးတိုင်းဒေသကြီးအတွင်း မင်းဝံတောင်တန်းဒေသနှင့် ကချင် ပြည်နယ်ရှိ ကသာ-ဂန့်ဂေါဒေသစသည့် နေရာ (၃) ခုသာ ဖြစ်ထွန်း ပေါ်ပေါက်သဖြင့် ရှားပါးစွာ မြင်တွေ့ရခြင်းလည်း ဖြစ်ပါသည်။ အဖိုးတန် ရှားပါးကျောက်မျက်ဖြစ်သော မိုးညှင်းနီလာ (ကျာယံနိုက်) ဖြစ်ပေါ်မှုသည် ဖိအားမြင့်-အပူချိန်နိမ့်အခြေနေတွင် ဒေသဆိုင်ရာ အသွင်ပြောင်း ကျောက် ဖြစ်ပေါ်မှု ဖြစ်စဉ်အတွင်း ၌သာ တွေ့ရှိရသော ကျောက်မျက် တစ်မျိုးလည်းဖြစ်ပြီး တွင်းထွက်တို့၏ အပူချိန်နှင့်ဖိအား ဖြစ်ပေါ်

မှုများကိုလည်း နားလည်သဘောပေါက်စေနိုင်ပါသည်။ ထို့ကြောင့် ဤဒေသတွင် ဘူမိဗေဒ ဘာသာရပ်ဆိုင်ရာ သုတေသနရှာဖွေလေ့လာမှုများ ပြုလုပ်နိုင်ရန် ဘွဲ့ကြိုနှင့် ဘွဲ့လွန်သင်တန်းသားများအတွက် စဉ်ဆက်မပြတ် ထိတွေ့ကွင်းဆင်း လေ့လာနိုင်သော ဘူမိသိပ္ပံ ဆိုင်ရာစိတ်ဝင်စားဖွယ် နေရာတစ်ခုအဖြစ် မှတ်တမ်းတင် ထိန်းသိမ်း ထားရှိ နိုင်ရေး အဆိုပြုတင်ပြရခြင်းဖြစ်ပါသည်။ ယခုကဲ့သို့ တွင်းထွက်မျိုးစုံ ပေါများကြွယ်ဝလှ၍ တွင်းထွက်ဘုံဟုပင် သတ်မှတ်ခေါ်ဆိုကြသော ဤဒေသအား ဘူမိသိပ္ပံဆိုင်ရာ စိတ်ဝင်စားဖွယ် နေရာ (Geosites) တစ်ခုအဖြစ် ထိန်းသိမ်းထား ရှိကာ ဘူမိဗေဒ၊ ကျောက်မျက်နှင့် တွင်းထွက်ဆိုင်ရာ များ လေ့လာနိုင်ရုံသာမဟုတ်ဘဲ ဘူမိဥယျာဉ် (Geopark)နှင့် ဘူမိခရီးသွားလုပ်ငန်း(Geotourism) အသွင်သို့ အဆင့်မြင့်ထိန်းသိမ်း ထားရှိနိုင်မည် ဆိုပါက ဘူမိအမွေအနှစ်နှင့် ဇီဝမျိုးစုံမျိုးကွဲများအား ထိန်းသိမ်းရာလည်းဖြစ်သည့်အပြင် ဒေသတွင်း စီးပွားရေးနှင့် လူမှုဘဝများ တိုးတက် စေနိုင်မည် ဖြစ်ပါသည်။

Potential Geosites Evaluation: Case Studies of the Mineral Paradise @ Mineral Occurrences of Shantaung-U and Shwe- Thar- Lyaung Hills, Kyaukse District, Mandalay Region; Pedagogical Implication Geoheritage and Geoconservation on Minerals and Rocks

1. Introduction

Geosites are sites of scientific interest based on geology or geomorphology that can serve various purposes, such as future research, conservation, education, tourism or sustainable development of a certain area (Lena and Carbone, 2016). A Geosite is a place with not only world heritage sites such as rocks, waterfalls, caves, hot springs, beaches, hot springs, rock formations, cliffs, and beautiful landscapes, but also plants, animals that are protected by the public and continuously studied, developed by the local socio-economic development, and fostered by the love of nature, and is a good place to study and create a pleasant environment for the new generation.

Geotourism is a tourism activity based on geology and landscape, which provides tourists with an opportunity to learn about the Earth's processes, and to experience the essence of peace and happiness. It has also attracted a lot of interest from foreign tourists. Geotourism is not based solely on geology, but also includes ecotourism, cultural heritage tourism to promote sustainable tourism (Fig. 1) (Blamey, 2001). Therefore, the country's natural heritage, Geosites have become popular internationally and research and evaluation activities have been promoted for the development of Geosites, Geoheritage, Geotourism, and Geoparks in the country (Myint Soe et al., 2018).

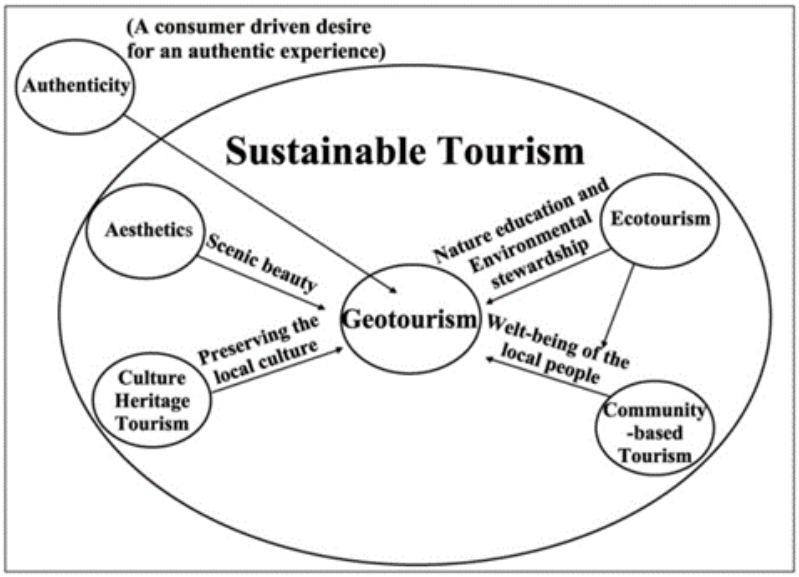


Fig. 1 Geotourism's place within Sustainable Tourism (Blamey, 2001)

A Geopark is primarily organized around geomorphically significant or geologically significant geosites, and aims to develop a sustainable socio-economic system for local residents and provide better employment opportunities through tourism, environmental conservation, education, and scientific research. A geopark is a designated area that centers around geologically or geomorphologically significant sites, aiming to foster sustainable socio-economic development for local communities. It promotes better employment opportunities through tourism, environmental conservation, education, and scientific research. To qualify as a geopark, a geosite is a group of locations that are identified, assessed, and systematically organized. Before achieving the status of a UNESCO Global Geopark, a site must first progress

through the Local Geopark and also National Geopark levels. In December 2023, Myanmar officially designated its first geopark: Mount Popa National Geopark. To reach the UNESCO Global Geopark level, a country must submit a proposal to UNESCO, followed by an assessment and evaluation by experts from the international Geopark Networks. In Myanmar, the Myanmar Geoscience Society spearheaded the establishment of Mount Popa as both a Local and National Geopark, taking the initial steps towards its recognition as a UNESCO Global Geopark (Myint Soe et al., 2018).

2. Purpose of Study

The present study is mainly focus on the following objectives:

(a) To protect the sites commonly used by Geology students for studying metamorphic rocks, preserving them from damage caused by natural processes or human actions such as resource extraction and urbanization;

(b) To provide data for academic and practical studies in geology, geomorphology, mineralogy, and related fields;

(c) To use geosites as outdoor classrooms for educating the public, students, and researchers about earth processes and history.

3. Geology of the Study Area

The Kyaukse area in Mandalay Region is a significant geological site. It hosts a variety of rock units, including metamorphic rocks, which showcase different metamorphic stages and mineral compositions (Fig. 2). Key minerals such as copper, lead, and barite are found in Kyaukse, offering opportunities to study metal inclusions and mineralization processes. This region is particularly valuable for examining the interplay of tectonic processes and mineral deposits, making it a critical area for geological research and resource exploration.

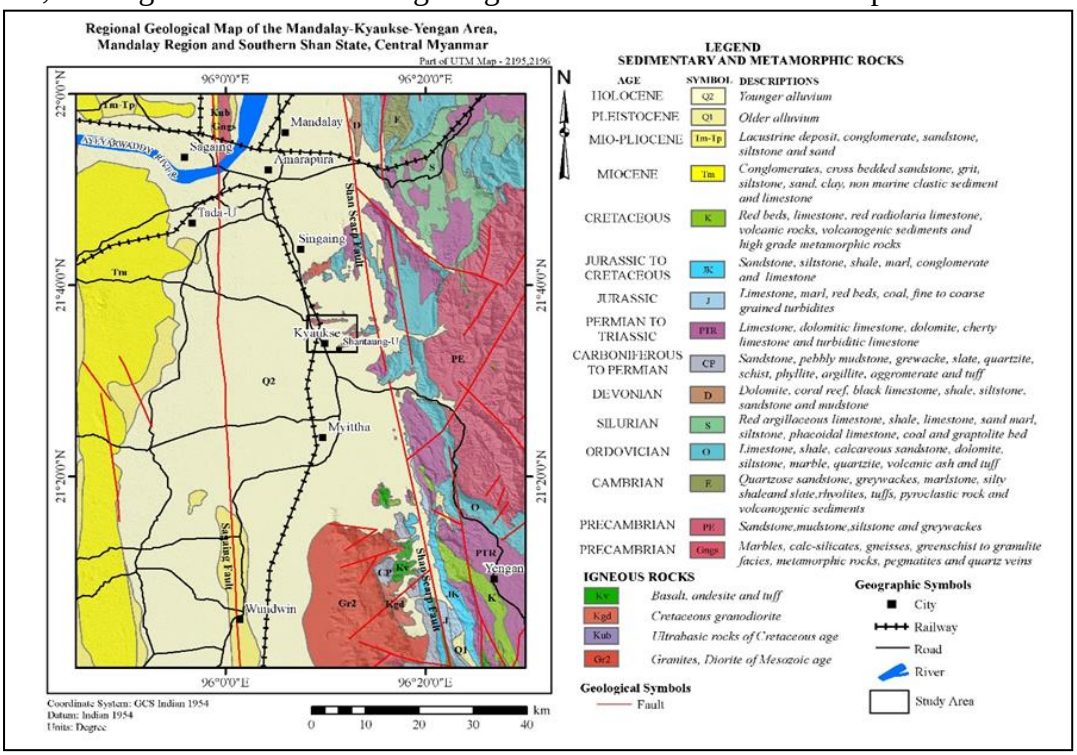


Fig. 2 Regional Geological Map of the study area (After D.G.S.E, 2008)

3.1 Shantaung-U Hill

The Shantaung-U Hill near Kyaukse is titled a mineralogist's paradise (Maung Thein and Soe Win, 1970). The Shantaung-U Hill (UTM-2196/02, 47Q /209000E, 2386000N) is located in a transitional zone between the Shan-Thanintharyi block to the east and the Central Cenozoic Belt to the west in terms of regional tectonic setting. The geological formation of the Shantaung-U Hill is related to the Himalayan Orogeny that occurred during the Cenozoic Era (Searle and Haq, 1964). In addition, it is located between two major faults, the Sagaing Dextral transform fault in the west and the Shan scarps fault in the east, which caused intense underground movements and caused severe deformation and metamorphic changes in the original sedimentary rocks, resulting in the discovery of metamorphic minerals. The host rocks, which are the Mogok Metamorphic Belts of Searle and Haq (1964), such as phlogopite marble, andalusite-phlogopite marble, garnet-staurolite schist, sillimanite schist and quartzite, are found to be inclined at a general angle of 30 degrees to the northeast and in some places, pegmatite dykes are found to be intruded. In these rocks, large and beautiful crystals of garnet, tourmaline, tremolite, actinolite, epidote, andalusite, chiastolite, sillimanite, kyanite, phlogopite, spinel and other minerals can be found in abundance in the Shantaung-U Hill (Kaung Htet Zaw, 2018) (Fig. 3).

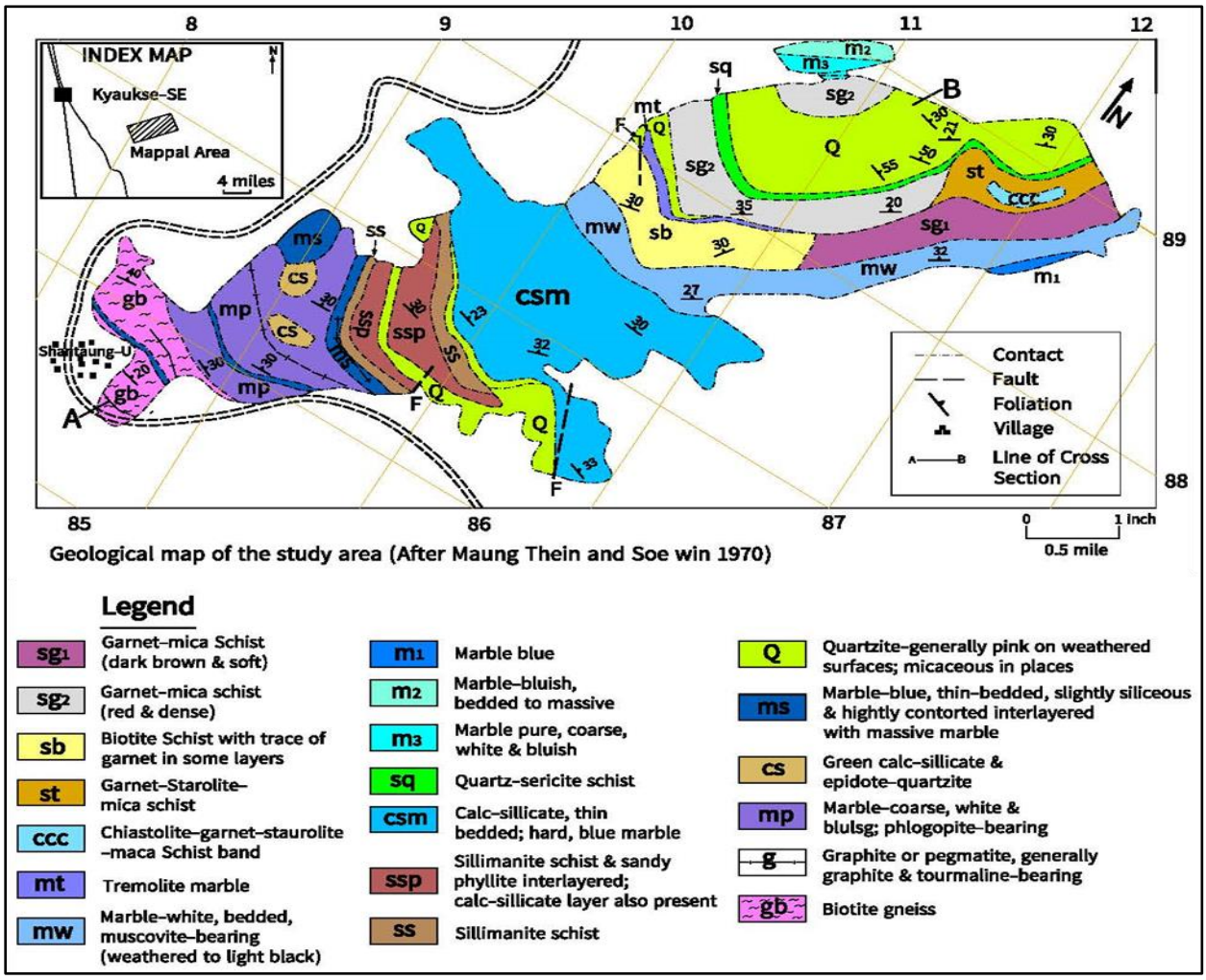


Fig. 3 Geological map and cross-section of the Shantaung-U Hill. (After Maung Thein and Soe Win, 1970 and Kaung Htet Zaw, 2018)

3.2 Shwe-Thar-Lyaung Hill (Kyaukse Hill)

Shwe-Thar-Lyaung Hill (Kyaukse Hill) is located east of Kyaukse and stands at an elevation of 275 meters (902 feet). At its summit lies a stupa believed to have been built by King Anawyahtar of Bagan. The site is situated around UTM Map 2196/01 (204815 E, 2391190 N) and is well-known for its religious significance, being a sacred and revered location among Buddhists, adorned with numerous stupas. From a geological perspective, the mountain offers significant study opportunities for students and researchers. (Myint Soe et al., 2024). Augen Gneiss is prominently exposed at the western part of the range, and the whole range is composed of calc-silicate rocks, quartzite & schist and garnet-andalusite-mica schist and pegmatite dykes including beryl are occurred (Nyein Chan Aung, 2018; Nyein Chan Aung et al., 2022). In the site, the blue marble which overlies the white variety was only partially recrystallised, whereas the white marble is completely crystalline. Additionally, Webu Series rocks are present, including biotite schist and bands of garnet-muscovite schist and tourmaline-muscovite gneiss. Psammatic phyllite interlayered with bands of diopside cale-silicate and sericite quartzite are also exposed (Maung Thein, 1993). Structurally, the rock layers strike northeast-southwest and dip 20–30° northwest. A high-angle thrust fault is also evident in Shwe-Thar-Lyaung Hill, making it an excellent location for fault studies. Near UTM Map Reference 2196/01 (205606 E, 2391284 N), a pegmatite dyke containing beryl (approximately 50 feet by 15 feet in size) is found intruding biotite schist at a dip of 85° (Nyein Chan Aung, 2018; Nyein Chan Aung et al., 2022) (Fig. 4).

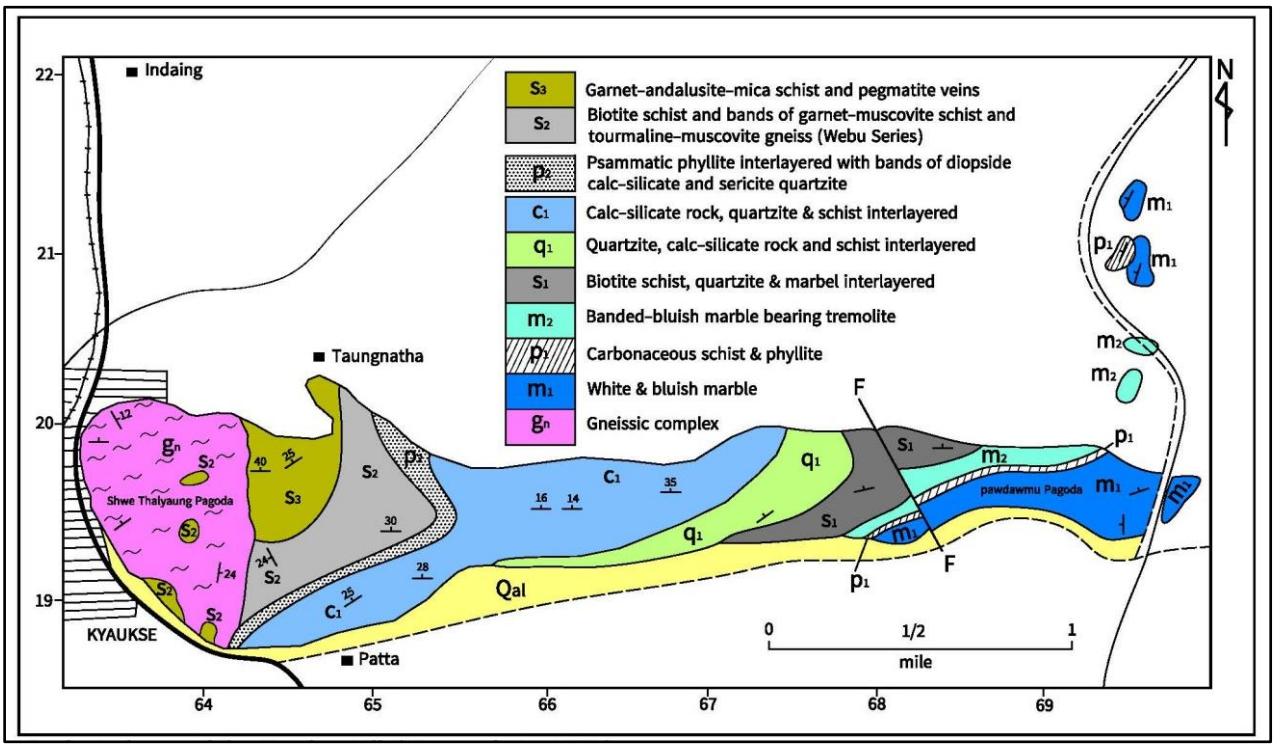


Fig. 4 Geological map of the Shwe-Thar-Lyaung Hill (Kyaukse Hill) (After Maung Thein, 1993)

4. Methodology

4.1 Methodology of Geosite Evaluation

In the present study, Geological potential sites were selected by using geosite evaluation guidelines of CLMTV Geosciences Working Group. This geosite guideline was created by Department of Mineral Resources (DMR) (2015), Thailand (Table 1).

Table 1. Geosite Evaluation Methodology (After Department of Mineral Resources, D.M.R. 2015)

Literature review & data collection, prepared desk study, reviewed for the accessibility and collected survey tools		**Geographical Information System (GIS)**		
		Geological & geomorphological base map	**Topographical base map & Satellite Image**	**Geoogle Earth Image**
Field Work and Geosite Exploration	Geotouristic itineraries	GPS data	Geomorphological map	Digital Elevation Model
Basic Geology Model and sketch	Tourist information	Geosite Database Attribute Table	Geosites & Geomorphosites	Loandsat 7 ETM Satellite Image
Geosite Evaluation Guide Lines	Cultural / Historical / Tourist Attraction Sites	Calculation Geosite Potential Score	Digital Mapping	Layer combination
Geosite Evaluation Form	Photographs	Writing Report	Review and Revise	Paper / poster
Workshop/Seminar/Meeting				
Geotouristic map of geosites & Geotouristic itineraries				
Submit proposal of Kyaukse Area Potential Geosites for National Geopark				

4.2 Scoring System for Geosite Evaluation

The geosite evaluation form which evaluates mainly academic value and development and management value (Fig. 5). Geosite evaluation guide is classified as important world class level, national uniqueness, part of country uniqueness, province uniqueness and no uniqueness compared with other sites. A geosite should have enough qualification for reference in terms of geology. The reference can be considered from many dimensions i.e. geological uniqueness, geological diversity, rareness, geological history evidence, aesthetic appreciation and diversity of landscapes. One or many dimensions are acceptable. Potential geosites must have scored greater than 50 for academic value (DMR, 2015).

Criteria	Weighting (W_k)	Important Level (S_{jk}) 1	2	3	4	5	Total (W_kS_{jk})	Remarks
1. Criteria for Academic value								
General (60)								
1. Geological uniqueness	15							
2. Geological diversity	10							
3. Rareness	20							
4. Geological history evidence	15							
Specific Criteria of Geo-morphological site (40)								
5. Aesthetic appreciation	20							
6. Diversity of landscapes	10							
7. Reference for geological aspect	10							
Total score	100	Average score						

Criteria	Weighting (W_k)	Important Level (S_{jk}) 1	2	3	4	5	Total (W_kS_{jk})	Remarks
2. Criteria for Development and Management								
Recent Developing Level (40)								
1. Suitable size and boundary	10							
2. Accessibility	10							
3. Facility	10							
4. Security	10							
Management Potential (30)								
5. Local people involvement	10							
6. Economic importance	10							
7. Geological knowledge distribution	5							
8. Zoning	5							
Development Potential (30)								
9. Necessary of Site Prevention	10							
10. Development Potential	10							
11.Other tourist attraction nearby	10							
Total score	100	Average score						

Fig. 5 Geosite Evaluation Form and Formula of Geosite Evaluation Score Calculation and Consideration of important level

4.3 Criteria for Academic Value

In the Geosite Evaluation Form, when considering the Important Level, the Geosite to be rated is 5 points if it is International level, 4 points if it is National level, 3 points if it is Regional and State level, 2 points if it is District level, and 1 point if it is Township level. Geological uniqueness is the geological outstanding features that make the site different/ remarkable/ unique from others. The following is the criteria after DMR (2015). (Table 2).

Table 2. Scoring system for Geosite Evaluation (Nazaruddin, 2018)

Important Level	Explanation
5	World class/ Regional uniqueness (e.g. SE Asia, Asia)
4	National uniqueness
3	Part of country uniqueness (e.g. northern, southern)
2	Province uniqueness
1	No uniqueness compared with other sites

Consideration: geological uniqueness can be defined in many dimensions such as the beauty, rareness, site formation, size and etc. compared with other sites in the same type.

5. Geosite Evaluation of the Study Area

5.1 Geosite Main Features

The area of Shantaung-U and Shwe- Thar- Lyaung Hills are selected for its geologic significance which are rich in various rock types including metamorphic as well as igneous and regarded by geologists as a "Mineralogist's Paradise". This area is intriguing region to study the formation of minerals and metamorphic processes. In this area, biotite-hornblende gneiss, various types of marbles including andalusite marble, various types of schists, including sillimanite schists, quartzite, calc-silicate rocks, phyllites and some pegmatite are well exposed. Metamorphic minerals such as garnet, tremolite, actinolite, diopside, forsterite, phlogopite, aluminosilicate polymorph minerals such as andalusite, sillimanite, kyanite (especially at Yinswe range), chiastolite, spinel, staurolite and tourmaline are found in this area. Moreover, the coexistence of andalusite, sillimanite and kyanite from the Yinswe range can be established as the triple point of these three polymorphs and contributed the P-T condition at about 4kb and 500°C (Kaung Htet Zaw 2018; Kaung Htet Zaw, et al., 2018).

Because of the abundance of these minerals and rocks, Shantaung-U and Shwe- Thar- Lyaung Hills will conserve for geological, mineralogical heritage as well as mineral diversity, geodiversity, geoheritage which leads to the sustainable development of geopark and geotourism, the local economy and the society. Moreover, the occurrence of pegmatite including beryls and associated metamorphic rocks and minerals of Mogok Metamorphic Belt from the Shwe-Thar-Lyaung-Hill are also deserved for the conservation of mineral heritage and geoheritage as a geosite. Some Igneous and Metamorphic Rocks and Minerals from in Shantaung-U and Shwe- Thar- Lyaung Hills are shown in (Fig. 6).

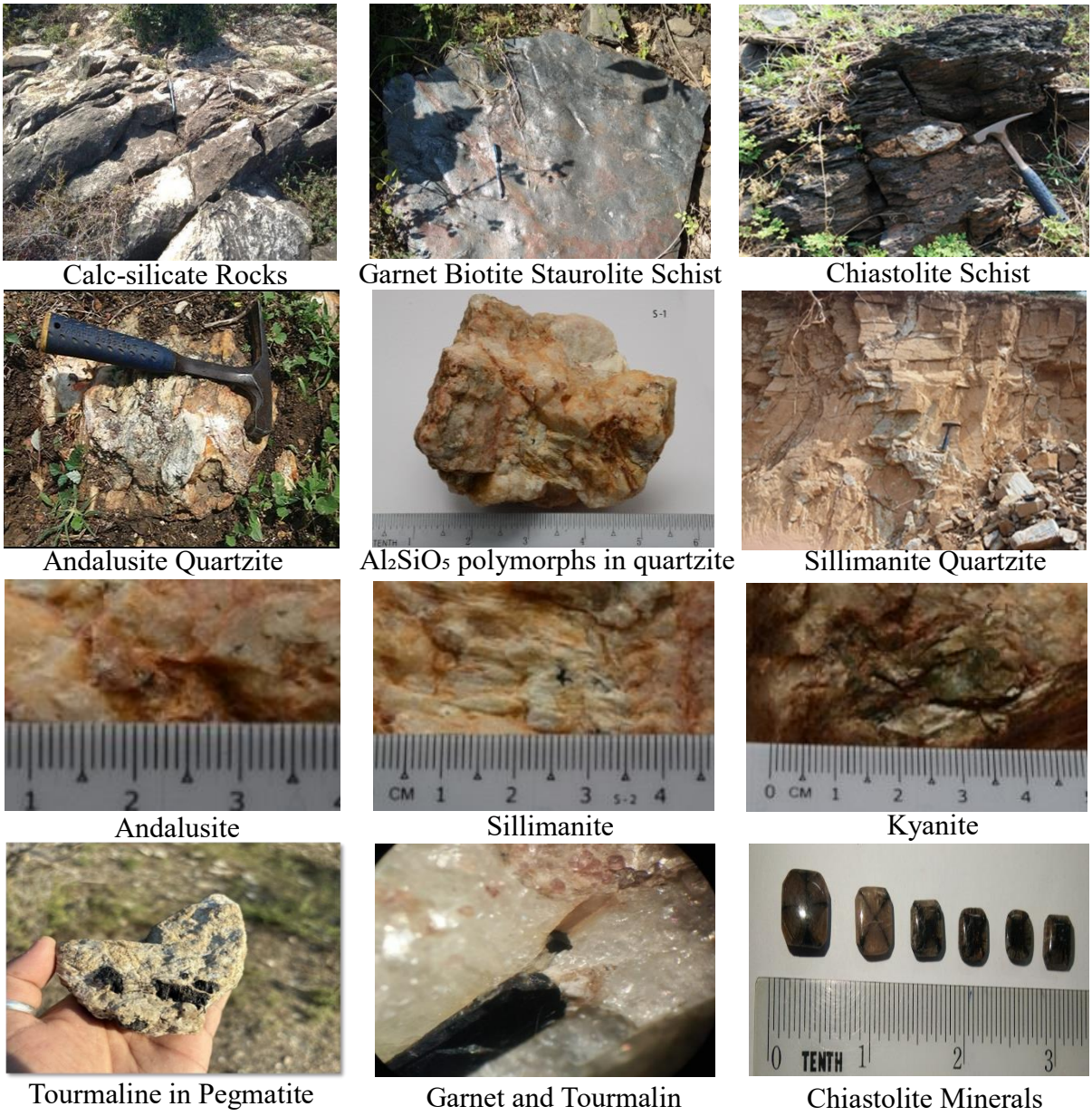


Fig. 6 Some Igneous and Metamorphic Rocks and Minerals from in Shantaung-U and Shwe-Thar- Lyaung Hills (Photos After Kaung Htet Zaw, 2018 and Myint Soe, 2024)

5.2 Geosite Classification

The selected geosites were categorized based on some classifications: geodiversity, scope, and scale. Geodiversity consists of eight elements: rock, mineral, fossil, landform, landscape, process, soil, and other georesources (Gray, 2005). In term of scope, (Brocx and Semeniuk, 2007) and (Predrag and Mirela, 2010) have classified geological sites into stratigraphic site, mineralogical site, fossil (paleontological) site, geomorphological site, speleological site, hydrological/ hydrogeological site, structural site, and so on. The sites can also be categorized based on their scale (Brocx and Semeniuk, 2007), such as regional scale (coverage of 100 x 100 km or larger), large scale (coverage of 10 × 10 km or larger), medium scale (coverage of 1 × 1 km or larger), small scale (coverage of 10-100 m x 10-100 m or larger), fine scale (coverage of 1 x 1 m or larger), and very fine scale (coverage of 1 × 1 mm or larger) (Nazaruddin, 2018). The classification of some selected geosites in Shantaung-U and Shwe- Thar- Lyaung Hills are shown in (Table 3).

Table 3. Classification of some selected geosites in Shantaung-U and Shwe- Thar- Lyaung Hills (modified after Myint Soe et al., 2023)

No	Geosite	Geodiversity (Grey, 2005)	Scope (Brocx and Semeniuk, 2007, Predrag D, Mirela, 2010)	Scale (Brocx and Semeniuk, 2007)
1.	Shantaung-U Hill	Rock/Mineralogy	Mineralogical Site/ Stratigraphic Site	Large Scale
2.	Shwe- Thar- Lyaung Hill	Landform/ Rock/Mineralogy	Geomorphology/ Stratigraphic Site	Large Scale

5.3 Geosite Assessment

In this study, two approaches were conducted to scientifically assess the geosites: the qualitative assessment (Table 4) and quantitative assessment (Table 5) show the geosites assessments of these selected geosites in the study area. The qualitative approach focuses on geoheritage values, mainly scientific (geological significances and interests) and educational (to train and educate people related to earth science and the general public), aesthetic (related to the beauty of the features), recreational (possibility for recreational and tourism activities), cultural (related to cultural and historical values), economic (the financial value of the features), functional (the uses or functions of the features), and etc. (Gray, 2004; 2005).

The quantitative approach was carried out to assess the sites numerically or to score the sites based on their geoheritage values and levels of significance (ranking). For the geoheritage values, there are six values which were established for this study: 0 = none, 1 = very poor, 2 = poor,3 = fair, 4 = good, and 5 = very good, meanwhile for levels of significance, there are five categories of values: 1 = local, 2 = regional, 3 = state-wide, 4= national, and 5 = international (after Nazaruddin, 2018).

Table 4. Qualitative Assessment of selected geosites for potential geoheritage resources and geotourism attractions in Shantaung-U and Shwe- Thar- Lyaung Hills (modified after Myint Soe et al., 2023)

Sr	Geosite	Scientific (and educational value)	Asthetic Value	Recretational value	Cultural (and historical value)	Economic value	Functional value	Religious Value	Level of significane
1	Shan taung-U Hill	Petrology, rock, mineralog y, geology	Land scape	Mineral beauty	Ancient Buddhist temples, statues	Local community can generate their income by visitors, researchers, students and mineral lovers	-	The temple for local and Buddhist people international	National

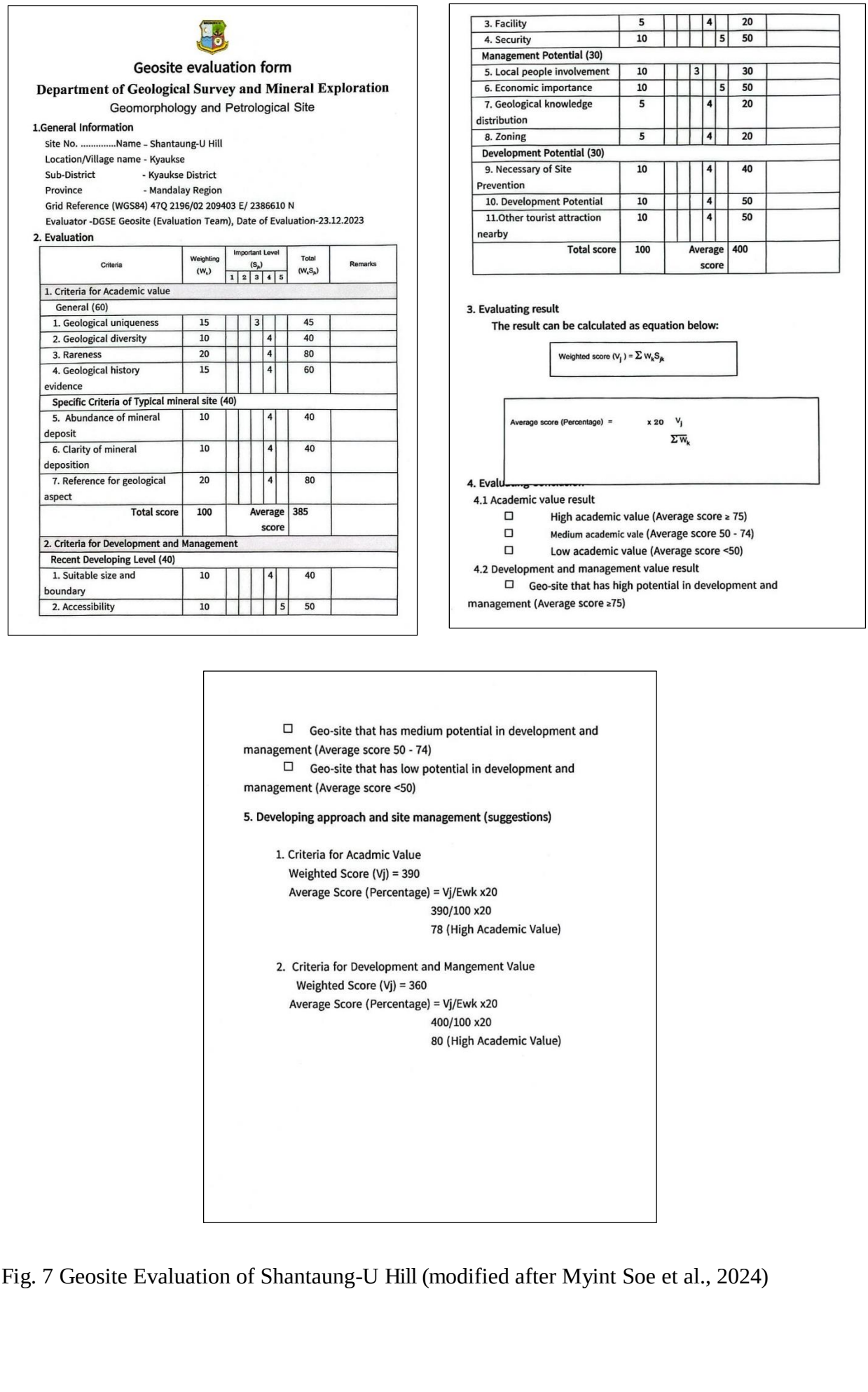
Sr	Geosite	Scientific (and educational value)	Asthetic Value	Recretational value	Cultural (and historical value)	Economic value	Functional value	Religious Value	Level of significane
2	Shwe-Thar-Lyaung Hill	Petrology, rock, mineralogy, geology	Land scape, view point	Enjoy the scenic views	Ancient Buddhist temples, statues	Local community can generate their income by visitors, researchers, students and mineral lovers	-	The temple for local and Buddhist people international	State

Table 5. Quantitative Assessment of selected geosites for potential geoheritage resources and geotourism attractions in Shantaung-U and Shwe- Thar- Lyaung Hills (modified after Myint Soe et al., 2023)

Sr.	Geosite	Scientific (and educational value)	Asthetic Value	Recretational value	Cultural (and historical value)	Economic value	Functional value	Religious Value	Level of significane	Total
1	Shantaung-U Hill	5	5	5	4	4	3	4	4	34
2	Shwe-Thar-Lyaung Hill	5	4	4	3	3	2	2	4	30

5.4 Geosite Evaluation of Shantaung-U and Shwe-Thar-Lyaung Hills

Based on evaluation score, these sites were identified and demarcated geotourism zone taking into account their scientific, educational and touristic values (Fig. 7 and 8). Potential geosites must have scored greater than 50 marks for academic value. Most of the geosites get high academic scores in Shantaung-U and Shwe-Thar-Lyaung Hills and have the potential to be designated as the geosite in Myanmar.



Geosite evaluation form

Department of Geological Survey and Mineral Exploration

Geomorphology and Petrological Site

1.General Information

Site No. .....Name - Shantaung-U Hill

Location/Village name - Kyaukse

Sub-District - Kyaukse District

Province - Mandalay Region

Grid Reference (WGS84) 47Q 2196/02 209403 E/ 2386610 N

Evaluator -DGSE Geosite (Evaluation Team), Date of Evaluation-23.12.2023

2. Evaluation

Criteria	Weighting (W_k)	Important Level (S_{jk}) 1	2	3	4	5	Total (W_kS_{jk})	Remarks
1. Criteria for Academic value								
General (60)								
1. Geological uniqueness	15			3			45	
2. Geological diversity	10				4		40	
3. Rareness	20				4		80	
4. Geological history evidence	15				4		60	
Specific Criteria of Typical mineral site (40)								
5. Abundance of mineral deposit	10				4		40	
6. Clarity of mineral deposition	10				4		40	
7. Reference for geological aspect	20				4		80	
Total score	100			Average score			385	
2. Criteria for Development and Management								
Recent Developing Level (40)								
1. Suitable size and boundary	10				4		40	
2. Accessibility	10					5	50	
3. Facility	5				4		20	
4. Security	10					5	50	
Management Potential (30)								
5. Local people involvement	10			3			30	
6. Economic importance	10					5	50	
7. Geological knowledge distribution	5				4		20	
8. Zoning	5				4		20	
Development Potential (30)								
9. Necessary of Site Prevention	10				4		40	
10. Development Potential	10				4		50	
11.Other tourist attraction nearby	10				4		50	
Total score	100			Average score			400	

3. Evaluating result

The result can be calculated as equation below:

$$\text{Weighted score } (V_j) = \Sigma W_k S_{jk}$$

$$\text{Average score (Percentage)} = \frac{V_j}{\Sigma W_k} \times 20$$

4. Evaluating conclusion

4.1 Academic value result

- ☐ High academic value (Average score ≥ 75)
- ☐ Medium academic vale (Average score 50 - 74)
- ☐ Low academic value (Average score <50)

4.2 Development and management value result

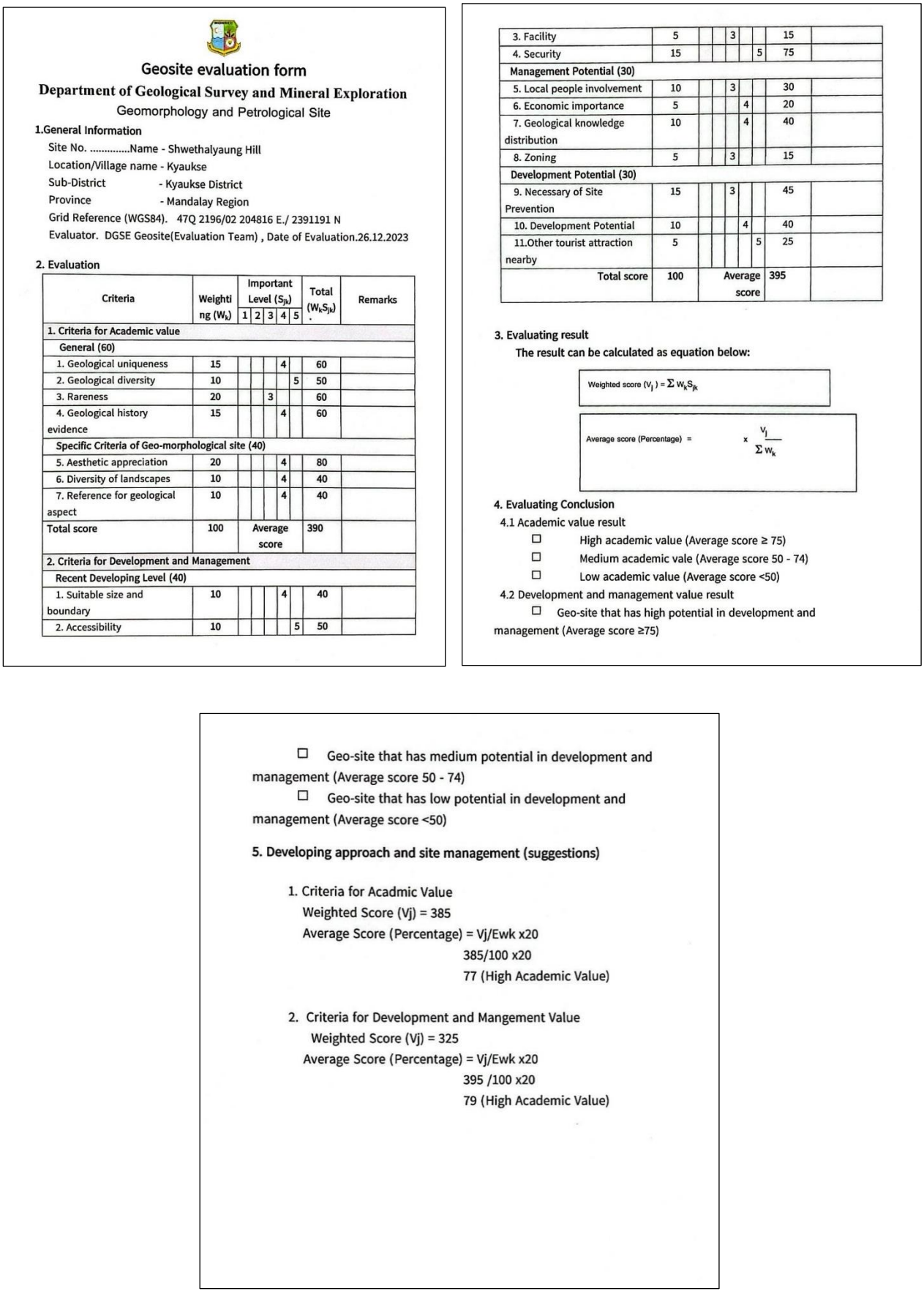
- ☐ Geo-site that has high potential in development and management (Average score ≥75)
- ☐ Geo-site that has medium potential in development and management (Average score 50 - 74)
- ☐ Geo-site that has low potential in development and management (Average score <50)

5. Developing approach and site management (suggestions)

1. Criteria for Acadmic Value
   Weighted Score (Vj) = 390
   Average Score (Percentage) = Vj/Ewk x20
   390/100 x20
   78 (High Academic Value)

2. Criteria for Development and Mangement Value
   Weighted Score (Vj) = 360
   Average Score (Percentage) = Vj/Ewk x20
   400/100 x20
   80 (High Academic Value)

Fig. 7 Geosite Evaluation of Shantaung-U Hill (modified after Myint Soe et al., 2024)



Geosite evaluation form

Department of Geological Survey and Mineral Exploration

Geomorphology and Petrological Site

1.General Information

Site No. .....Name - Shwethalyaung Hill
Location/Village name - Kyaukse
Sub-District - Kyaukse District
Province - Mandalay Region
Grid Reference (WGS84). 47Q 2196/02 204816 E./ 2391191 N
Evaluator. DGSE Geosite(Evaluation Team) , Date of Evaluation.26.12.2023

2. Evaluation

Criteria	Weighting (W_k)	Important Level (S_{jk}) 1	2	3	4	5	Total (W_kS_{jk})	Remarks
1. Criteria for Academic value								
General (60)								
1. Geological uniqueness	15				4		60	
2. Geological diversity	10					5	50	
3. Rareness	20			3			60	
4. Geological history evidence	15				4		60	
Specific Criteria of Geo-morphological site (40)								
5. Aesthetic appreciation	20				4		80	
6. Diversity of landscapes	10				4		40	
7. Reference for geological aspect	10				4		40	
Total score	100	Average score					390	
2. Criteria for Development and Management								
Recent Developing Level (40)								
1. Suitable size and boundary	10				4		40	
2. Accessibility	10					5	50	
3. Facility	5			3			15	
4. Security	15					5	75	
Management Potential (30)								
5. Local people involvement	10			3			30	
6. Economic importance	5				4		20	
7. Geological knowledge distribution	10				4		40	
8. Zoning	5			3			15	
Development Potential (30)								
9. Necessary of Site Prevention	15			3			45	
10. Development Potential	10				4		40	
11.Other tourist attraction nearby	5					5	25	
Total score	100	Average score					395	

3. Evaluating result

The result can be calculated as equation below:

$$\text{Weighted score } (V_j) = \Sigma W_k S_{jk}$$

$$\text{Average score (Percentage)} = x \frac{V_j}{\Sigma W_k}$$

4. Evaluating Conclusion

4.1 Academic value result

- ☐ High academic value (Average score ≥ 75)
- ☐ Medium academic vale (Average score 50 - 74)
- ☐ Low academic value (Average score <50)

4.2 Development and management value result

- ☐ Geo-site that has high potential in development and management (Average score ≥75)
- ☐ Geo-site that has medium potential in development and management (Average score 50 - 74)
- ☐ Geo-site that has low potential in development and management (Average score <50)

5. Developing approach and site management (suggestions)

1. Criteria for Acadmic Value
   Weighted Score (Vj) = 385
   Average Score (Percentage) = Vj/Ewk x20
   385/100 x20
   77 (High Academic Value)

2. Criteria for Development and Mangement Value
   Weighted Score (Vj) = 325
   Average Score (Percentage) = Vj/Ewk x20
   395 /100 x20
   79 (High Academic Value)

Fig.8 Geosite Evaluation of Shwe-Thar-Lyaung Hill. (modified after Myint Soe et al., 2024)

6. Applicability of the Study Area

This area is invaluable for geological research, particularly for postgraduate studies and as a training ground for undergraduate students. It offers as an open classroom where geology students can directly observe and analyze metamorphic rocks and minerals and bridge the gap between theoretical knowledge and real-world applications, depending their understanding of geological concepts and gaining practical skills in mineral identification, field mapping and geological training. In this area students had the possibility to be stimulated to apply their knowledge thanks to the direct observation in the field, increasing their interest in the topics under study. For postgraduate students, it offers a unique and resource-rich environment for in-depth research into mineral formation, metamorphic transformations, and P-T condition of the area. Since the chosen areas respond to scientific-educational and practical logistics requirements, students of different age can use them to study scientific topics at different degree of deepening. The teaching material created form this site allows to organize school trips in order to observe directly the themes previously studied at school, to collect data and information in the field and to elaborate them back to school. This area serving as pedagogical use, a versatile mineral in geological education, helping illustrate concepts in mineralogy and petrology for geologists.

These minerals highlight essential geological processes like metamorphism and magmatism but also contribute significantly to various mineralogical processes. Their distinct physical and chemical properties make them indispensable for geological education, offering a practical understanding of pressure-temperature conditions, magma and fluid evolution, and metamorphic processes make them indispensable resources for advancing geological knowledge.

7. Benefits

By promoting this Mineralogist's Paradise as a part of geosite, it will conserve for geological, mineralogical heritage as well as geodiversity, geoheritage which leads to the sustainable development of geopark and geotourism, the local economy and the society. The occurrence of pegmatite and associated metamorphic rocks and minerals of Mogok Metamorphic Belt from the Shwe-Thar-Lyaung-Hill are also deserved for the conservation of geoheritage as a geosite.

Since there is a large Mineral's Paradise, the country attracts researchers and gemologists nationwide to carry out studies and produce academic works, creating opportunities for foreign exchange earnings, contributing to national development and yielding substantial advantages for the country. For the Geotourism Development, it can promote the mineralogist's paradise as a geotourism destination which generate revenue and create awareness about conservation. Participating in the search for potential sites for the country's National Geoparks and the development of National Geopark proposals, which is one of the department's responsibilities.

8. Conclusion

The Shantaung-U and Shwe-Thar-Lyaung Hills area geologically significant region renowned for its rich diversity of rocks and minerals, earning its title as a "Mineralogist's Paradise". The presence of metamorphic and igneous rocks, such as biotite-hornblende gneiss, marbles, schists, quartzite, calc-silicate rocks, and pegmatites including beryl, alongside an

impressive suite of minerals like kyanite, sillimanite, andalusite, chiastolite and garnet makes this area a vital resource for geological research and education.

Among these metamorphic minerals, especially aluminosilicate polymorphs, kyanite, for example, is considered as a rare gem mineral compared to other minerals and their occurrences are limited in Myanmar especially occurred in at least 3 places namely Kathar-Gangaw range in Kachin State, Min Wun range and Shantaung-U range in Mandalay Region. Kyanite is unusual mineral and can be used as a metamorphic indicator because it could be formed under high-pressure, low-temperature conditions, commonly found in regional metamorphism of pelitic rocks.

This site offers exceptional opportunities for academic and practical training and serves as a natural laboratory where theoretical knowledge can be applied to real-world scenarios, enhancing their understanding of mineralogy, petrology, and field geology. Postgraduate researchers benefit from its unique assemblages to study mineral formation, metamorphic processes, and P-T conditions, making it a rich resource for advancing geological science.

Beyond its academic value, the site supports sustainable development through its potential for geotourism, mineralheritage and geoheritage conservation. It offers an ideal platform for promoting public awareness of geology while contributing to the local economy.

In conclusion, the Shantaung-U and Shwe-Thar-Lyaung Hills are treasure trove of geological, petrological and mineralogical knowledge. Its preservation as a geosite is crucial for fostering education, research, and sustainable geotourism while highlighting the intersection of Earth's natural processes and human utility. Protecting and promoting this area ensures its continued contribution to both scientific advancement and societal benefit.

9. Acknowledgement

The authors would like to express our thanks to the Ministry of Natural Resources and Environmental Conservation and also Department of Geological Survey and Mineral Exploration for granting us the opportunity to undertake this research. We extend our sincere appreciation to the Dr. Thet Tin Nyunt, Director General, Department of Geological Survey and Mineral Exploration, whose encouragement and support have been instrumental in enabling us to carry out this research. His leadership and vision have greatly inspired us. We would also like to thanks to Department of Forest, Organizer of this conference.

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