Geochemical Characterization of Gypsum in Minhla and Minbu Areas, Magway Region, Myanmar

Pyi Soe Thein[1], Nwe Nwe San[2], Kyi Hlaing[3]

Abstract

We present the detailed geochemical characteristics of the gypsum association of Pyawbwe Formation in Minhla and Minbu areas of the Minbu Basin in Magway region. Early Miocene in Pyawbwe Formation is composed of bluish gray sand clay with dispersed gypsum plates, concretionary blue-gray clays, intraformationl conglomerates and subordinate sandstone. Gypsum is fibrous to crystalline and transparent type with fluid inclusions preserved in it. In this research, samples were also collected from four locations in Minhla area and two locations in Minbu area, Magway region. Energy Dispersive X-ray fluorescence spectrometer (ED-XRF) study confirmed the main constituent of the collected samples are calcium, Ca and sulphur, S. In the collected samples, Ca and S contents are ranging from 61 to 67 mass % and 17 to 28 mass %, respectively. From the X-ray diffractometer (XRD) analysis, all the peaks of the collected samples are identical to the XRD pattern of monoclinic phase gypsum, $CaSO_4{\cdot}2H_2O$. Thermogravimetric analysis (TGA) results show the complete dehydration of collected samples from different sites (gypsum, $CaSO_4.2H_2O$) is the loss of water molecules and corresponds to the weight loss about 20%. ED-XRF, XRD and TGA results confirm that the collected samples from different sites are gypsum. We propose that gypsum veins in Pyawbwe Formation may have precipitated in the fractures formed due to pressure/forces generated by crystal growth. The combined results of geochemical studies have shown that these techniques have significant potential to identify the pure/mineral associates/similar chemical compositions elsewhere. Our results definitely provide the database from a range of ED-XRF, XRD and TGA techniques to better identify similar minerals and/or mineral-associations in an extraterrestrial scenario. This study has significant implications in understanding various geological processes and alteration processes involving water on the earth.

Keywords: Gypsum, ED-XRF, XRD and TGA

Introduction

Gypsum is one of the most common evaporitic minerals in the geological record and the most frequent in outcrop due to its lower solubility compared with other evaporites such as halite, glauberite, etc. Even though halite is the main precipitation phase from the sea water, it is rapidly altered and, therefore, it is poorly or not preserved in outcrop (Schreiber,2000). The main objective of our work is to establish a detailed surface quantification of the different gypsum-bearing units present in the geological record of the Minhla and Minbu areas, Magway region, where gypsum is one of the major outcropping industrial minerals. The currently available digital technologies, such as Geographic Information Systems (GIS), allow integrating and analyzing an enormous amount of geographical and geological information. In addition, public databases offered by different institutions, provide the basic information such as topography, geology, urban areas, infrastructures and protected areas to be used by GIS software. In this study, the analysis and evaluation of the outcrops of evaporite-bearing geological units have been accomplished using ArcGIS. The main raw data was obtained from digital and paper collection of Geological Map of Myanmar, scale 1:50000. We report here the results of various chemical and spectral analytical techniques employed on the gypsum in Minhla and Minbu areas, Magway region. Location map of the research area is shown in figure 1.

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Tectonic Setting

Myanmar lies at the junction of the Alpine–Himalayan Orogenic Belt and the Indonesian Island Arc System. In northern Myanmar, the orogenic belt is bent around the Eastern Himalayan Syntaxis into a north–south direction and passes southwards through the resource-rich Indo-Myanmar Ranges (Khin Zaw, 2017), (Hla Htay.et.al, 2017) and (Barber.et.al, 2017) into the Andaman and Nicobar islands, Sumatra and the Sunda and Banda arcs of Indonesia. The Himalayas and the mountain ranges of northern Myanmar mark the collision between the Indian subcontinent and the southern margin of the Eurasian continent. Detritus from the Himalayas, transported by the rivers Ganges and Brahmaputra, has built an extensive delta into the Bay of Bengal on Indian Ocean crust. At the present day the Indian Tectonic Plate, carrying India and the Indian Oceanic Crust, is moving north eastwards at 5 cm a^{-1}, and is moving past Myanmar on transcurrent faults. The collision between Indian continental crust and Eurasia continues at the Eastern Himalayan Syntaxis; to the south in Myanmar collision occurred earlier in the Indo-Myanmar Ranges, resulting in the Patkai Range and the Naga and Chin hills. Further south, the overlying sediments of the Bengal Fan have been affected by transcurrent faulting and transpression to form a fold-and-thrust belt in the Rakhine Yoma. (Curray.et.al,1979) defined a Burma (Myanmar) Microplate, delimited to the west by the active Andaman subduction zone and a major strike-slip fault between the Indian Plate and Myanmar, and to the east by the north–south-aligned strike-slip Sagaing Fault. The research area is situated in the southwestern part of Minbu Basin. It is bounded in the east by Central Pluto-Volcanic Line, in the west by Western Ranges, in the north by Wuntho Mass Uplift and Chindwin Basin, and in the south by Pyay basin respectively. The origin of basin is closely related to the evolution of the Indo-Burma Range, which in tum associated with the convergence of Indian oceanic and Asia continental plates during Tertiary. The study area is located in the southern edge of Salin Syncline.

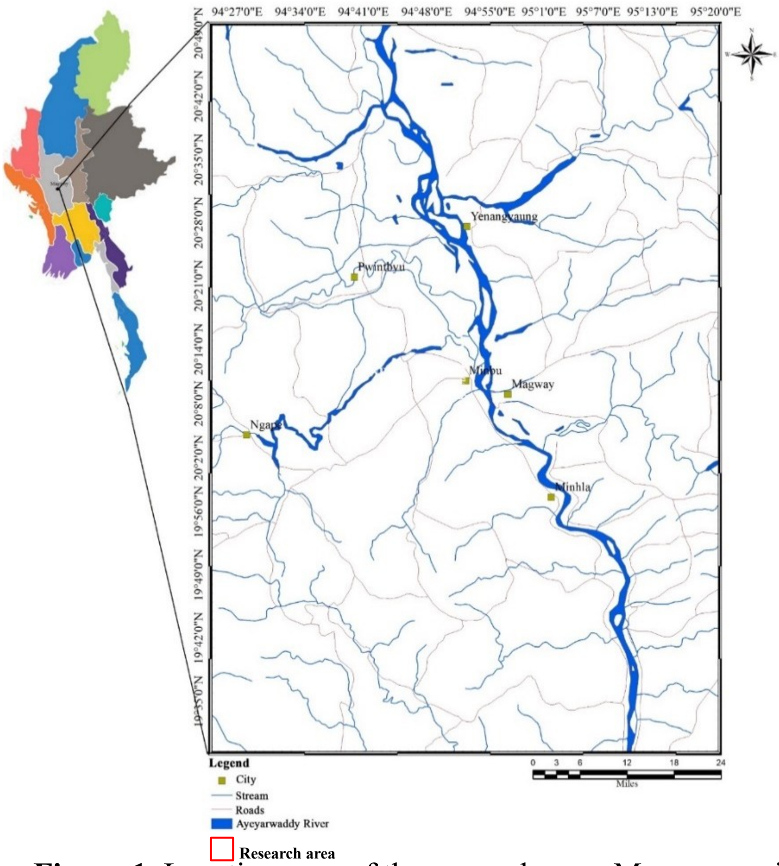

Figure 1. Location map of the research area, Magway region.

Stratigraphy

The research area is lying in the southwestern part of the Minbu Basin and composed almost completely of Tertiary clastic sediments. Six stratigraphic units of formation rank can be classified which are in ascending orders:

(6) Irrawaddy Formation (Late Miocene-Pliocene)
Unconformity
(5) Obogon Formation (Middle Miocene)
(4) Kyaukkok Formation (late Early Miocene)
(3) Pyawbwe Formation (early Early Miocene)
Unconformity
(2) Okhmintaung Formation (Late Oligocene)
(1) Padaung Formation (late Early Oligocene)

Although there are six lithostratigraphic units in the area, the present study carried out especially on the Pyawbwe Formation.

Pyawbwe Formation

The name Pyawbwe stage was firstly introduced by Lepper in 1933 for a succession which exposed near Pyawbwe village in the Minbu townsip. It is constituted of grayish-blue sandy clays with disseminated gypsum plates. Later, these strata are grouped under a lithostratigraphic unit and referred to as the "Pyawbwe Formation" by Aung Khin and Kyaw Win (1969). It is characterized by pale grey to bluish gray shale, clay and calcareous mudstone with subordinate sandstones, occasionally intercalated with indurated sandstone bands with ripples marks and cross beddings. The bluish grey clay units are frequently interbedded with reddish brown, friable sandstone. Some intraformational conglomerate can be observed in this formation. Rounded concretions and disc shaped concretion are present in this unit. Iron nodules are numerous throughout the clay unit. Fossiliferous sandstone bands are abundantly observed. Various types of burrows, wood chips and mud clasts are also present. The Pyawbwe Formation unconformably overlies the succeeding Okhmintaung Formation and gradationally underlies the Kyaukok Formation. In the Central Myanmar Basin, the Late Oligocene is separated from the Early Miocene by an unconformity. The gastropods such as *Crisotrema chipolanum, Psammostoma costatum* and *Parametaria bella* can be identified from the Pyawbwe Formation of the Magway region (Phone Thida Kyaw 2016). These fossils indicate the age of the Pyawbwe Formation may be early Miocene and it can be correlated with the Letkat Formation of the Chindwin Basin and Shwetaung Clay of Taungtalon area (Myint Thein, 1966).

The GIS-Based Model

The GIS based model involves three types of objectives. These are interpretation of vector, tabular and raster database. The imageries such as aerial photographs and satellite images were used for the generation of stereo-pairs in order to generate geomorphological map of Magway region (figure 2). The necessary analysis was carried out for the generation of GIS layer models and lithological cross section. The strategy for geochemical characterization of gypsum assessment is shown in figure 3.

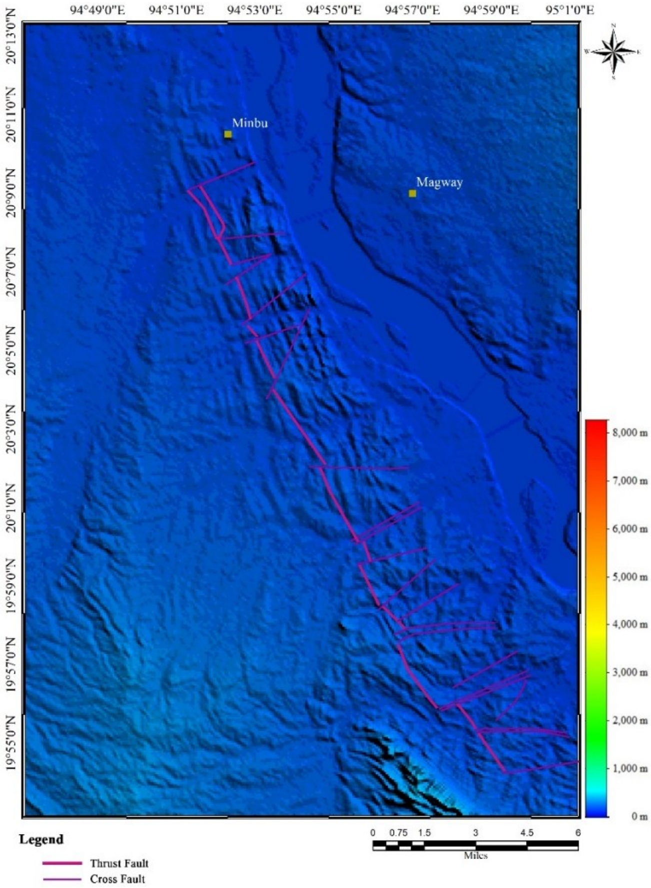

Figure 2 Digital Elevation Modal of Magway region, Myanmar.

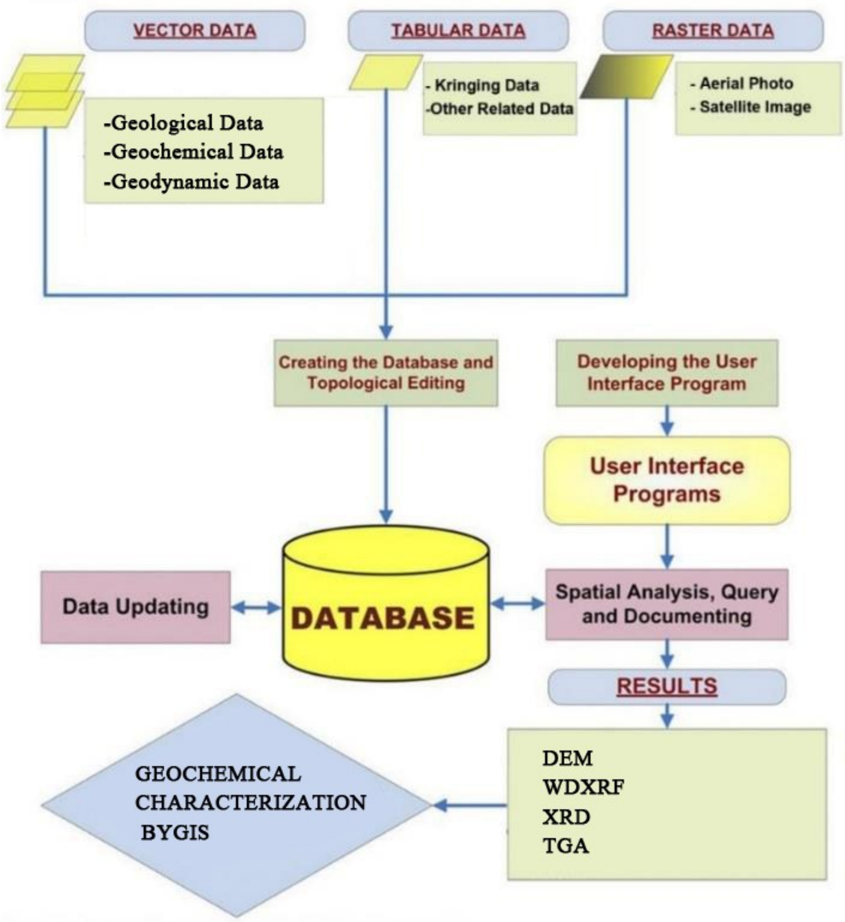

Figure 3. Data Workflow of Gypsum in Minhla and Minbu areas, Magway region.

Materials and Methods

Site Selection, Sampling and Sample Preparation

Gypsum deposits from Minhla and Minbu areas, were mapped, and samples were collected from each site for further laboratory analyses. Gypsum deposits were noticed in different forms ranging from veined, surficial, to layered type. Samples were also collected from the badland topographic setting of Minhla and Minbu areas, Magway region (figure 4 to 9). The samples collected were of gypsum from different depositional settings. Collected samples cleaned and crushed using Fritsch Pulverisette with Ni-Ch grinding set attached with air compressor and a Jaw Crusher (Insmart Systems) for preparing the samples for various chemical analyses such as X-ray fluorescence (XRF) and Termogravimeter Analysis (TGA). X-ray diffraction (XRD) analyses were carried out with the powder samples. The representative samples were crushed and ground into powder solid with a particle size of approximately 48 μm. A total of 10 g was collected and sealed for each kind of gypsum sample. Geochemical analysis of gypsum was done in University Research Center at Yangon Technological University, University of Magway and University of Yangon, Myanmar.

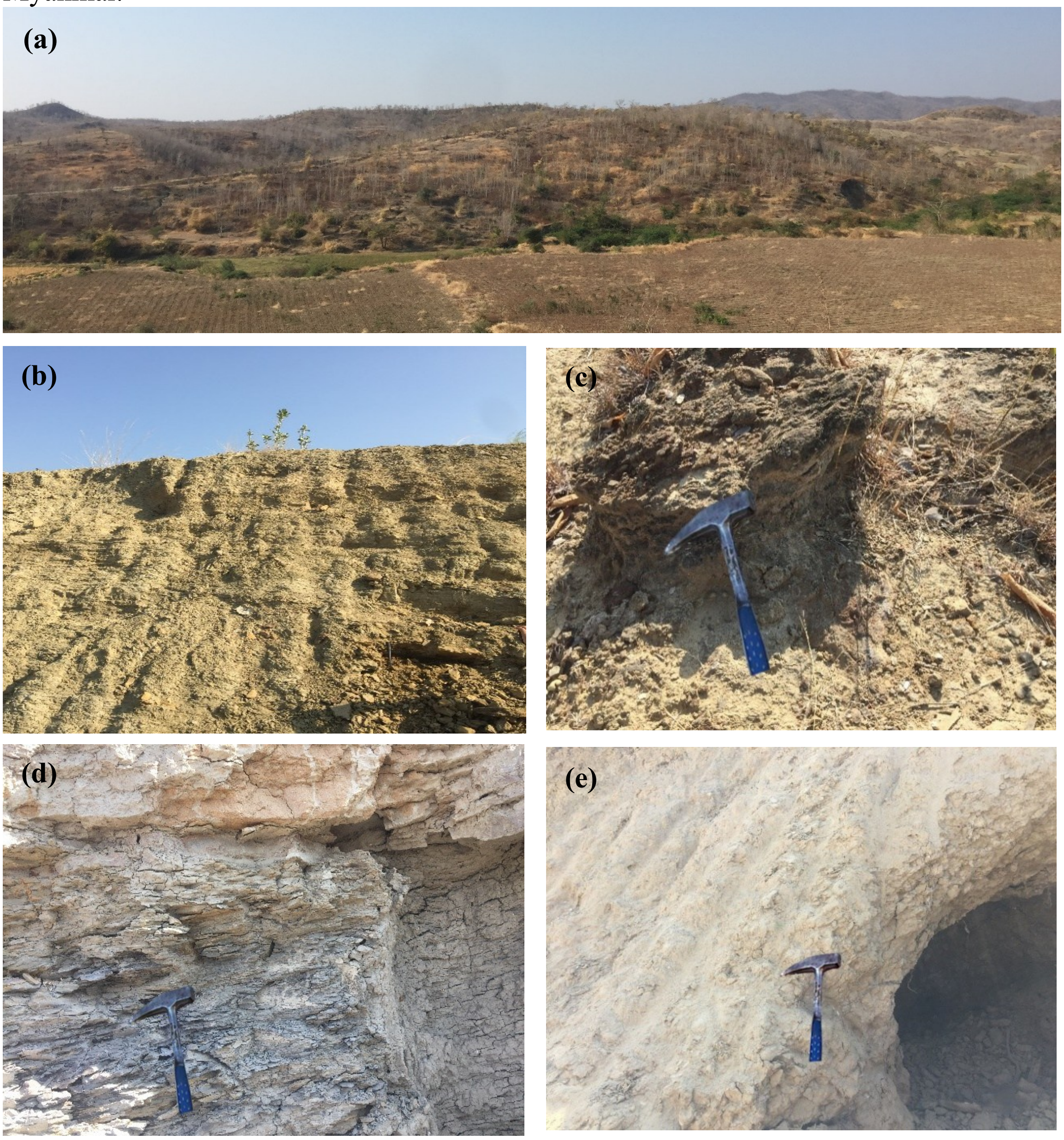

Figure 4. Field photographs showing (a) badland topographic setting in Minhla area, Magway region (b) gypsum deposits on site no G1 (19°53'53"N & 95°01'13"E), (c) top view of gypsum in site no G2 (19°53'40"N & 95°01'50"E),, (d) a vertical gypsum vein is exposed in site no G3 (19°54'30"N & 95°02'03"E), and (e) irregular small scale gypsum veins in site no G4 (19°55'43"N & 94°57'40"E).

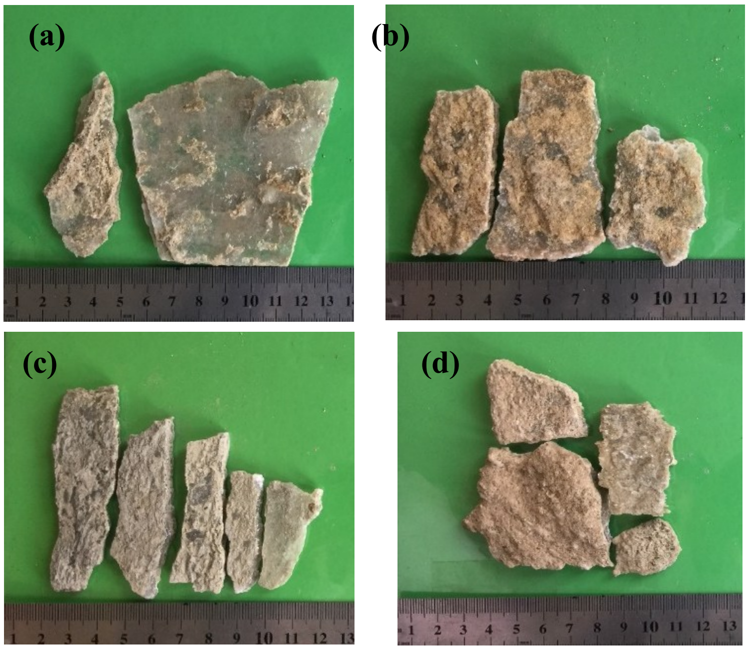

Figure 5. Photograph of the samples (a) site no G1, (b) site no G2, (c) site no G3 and (d) site no G4, Minhla area, Magway Region.

Figure 6. Location map of the sample sites at Minhla area, Magway region

Figure 7. Field photographs showing (a) Interbedded unit of sandstone and shale in Pyawbwe Formation in Minbu area, Magway region (b) gypsum deposits on site no 1 (M1) (20°9'23"N & 94°53'79"E), (c) top view of gypsum in Pyawbwe Formation (20°9'17"N & 94°53'09"E),, (d) The bluish grey clay units are frequently interbedded with friable sandstone (20°9'15"N & 94°53'93"E) and (e) irregular small scale gypsum veins in site no 2 (M2) (20°9'15"N & 94°53'14"E).

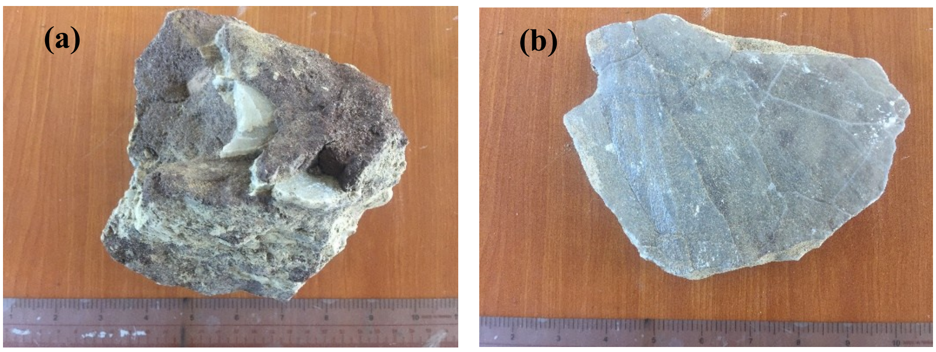

Figure 8. Photograph of the samples (a) site no 1 (M1), (b) site no 2 (M2), Minbu area, Magway Region.

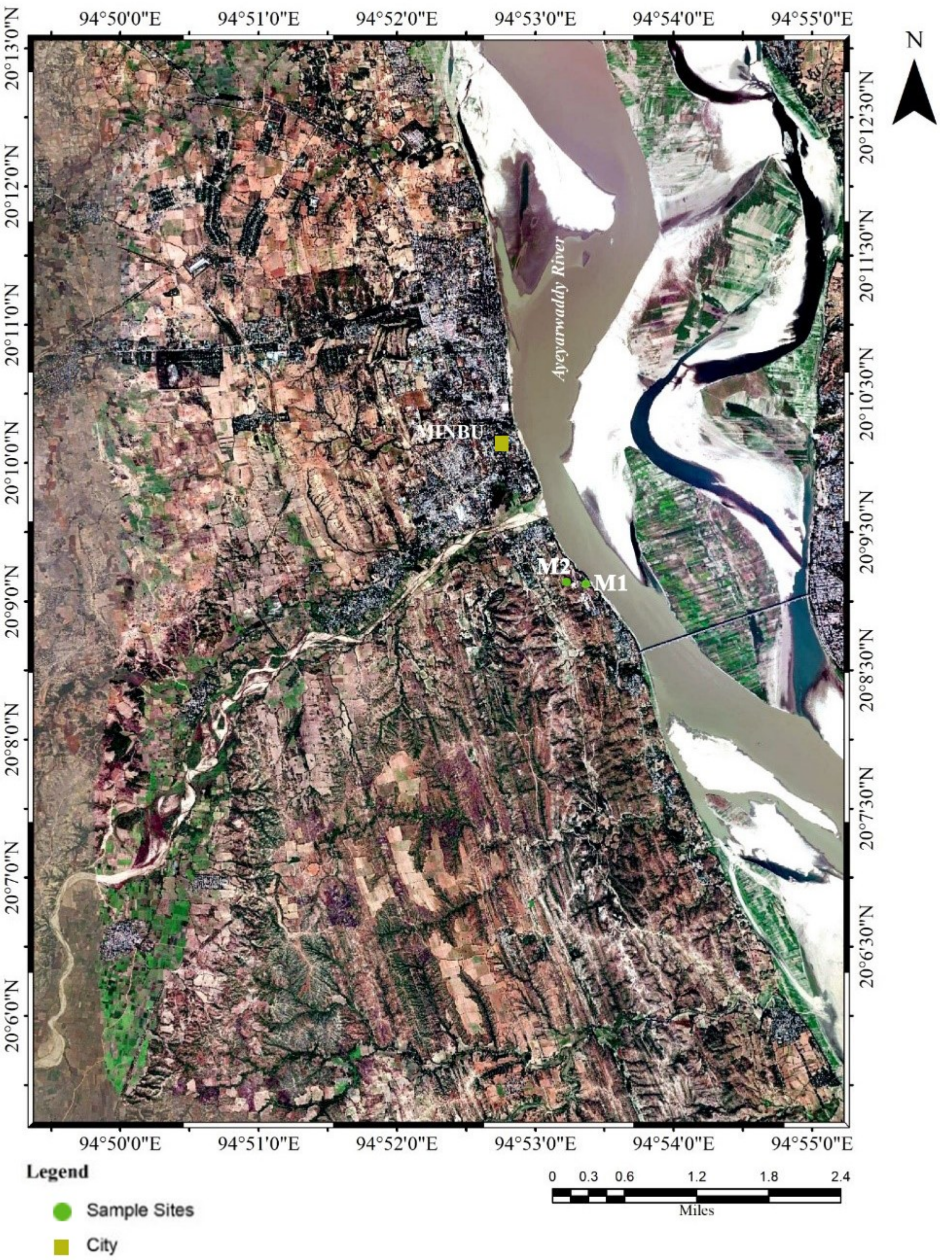

Figure 9. Location map of the sample sites at Minbu area, Magway region.

Results and Discussions

ED-XRF Analysis

The elemental composition of the collected samples (G1-G4) from different sites of Minhla area and (M1 and M2) from different sites of Minbu area was determined using Energy Dispersive X-ray fluorescence spectrometer (EDXRF) and the results are presented in Table 1. EDXRF study confirmed the main constituent of the collected samples are calcium, Ca and sulphur, S. In the collected samples, Ca and S contents are ranging from 61 to 67 mass % and 17 to 28 mass %, respectively. The percentages of other elements listed in Table 1 are found in low concentrations. The results indicate that the collected samples from different sites are gypsum.

Table 1. Elemental composition of the collected samples (G1-G4) and (M1, M2).

Sites	Elemental composition (%)												
	Ca	*S*	*Fe*	*Si*	*Mn*	*K*	*Ti*	*Sr*	*Mg*	*Zr*	*Cu*	*Al*	*Mn*
G1	62.961	27.957	2.001	2.623	0.112	1.286	-	0.318	1.367	0.042	0.012	1.310	0.011
G2	62.582	23.564	2.003	4.250	0.051	3.013	0.698	0.162	1.200	0.014	0.064	2.380	0.020
G3	65.331	16.685	2.460	7.610	0.121	1.507	0.248	0.593	2.650	0.072	0.015	2.695	0.012
G4	63.587	26.771	1.005	2.301	-	1.670	0.419	0.117	2.810	0.032	0.058	1.230	-
M1	66.918	17.225	10.266	-	2.435	1.973	0.742	0.241	0.071	0.053	0.046	0.030	-
M2	61.162	28.308	4.338	4.182	0.141	1.261	0.315	0.173	-	0.012	0.031	0.077	-

X-ray diffraction Analysis

To confirm the ED-XRF results, phase purity analysis of the collected samples was performed on the XRD 6100 instrument. The XRD pattern's 2-theta range was from 5° to 55° with using steps of 0.01°. Before analyzing the samples, the machine was calibrated with a standard silicon reference. For X-ray diffraction, a copper tube made of ceramic (Cu Ka, 1.54060 °A) was chosen as the X-ray source, and the temperature of the tube was maintained by a chiller operated at 23° C. To produce X-rays, the voltage and current were used at 40 kV and 30 mA, respectively. The ICDD PDF database was used to identify the phase. The XRD patterns of the collected samples (G1-G4) from different sites of Minhla area and (M1 and M2) from different sites of Minbu area are shown in figure 10 and figure 11. All the diffraction peaks of the collected samples are at 2-theta values of about 11° , 20°, 23°, 29°, 31°, 33°, 40°, 47° which can be assigned to the crystal planes (020), (021), (040), (041), (-221), (220), (151) and (080) of gypsum, $CaSO_4 \cdot 2H_2O$. All the peaks of the collected samples are identical to the XRD pattern of monoclinic phase gypsum, $CaSO_4 \cdot 2H_2O$ in the ICDD database (card no.: #00-033-0311). In the XRD patterns of M1 and M2, the minor impurity peak was found at 2-theta value of about 27°. All the major diffraction peaks of collected samples are matched well with the reported research (Mahima Singh.et.al, 2017), (Eko Pujiyanto.et.al, 2014). Thus, ED-XRF and XRD results indicate that the collected samples from Minhla and Minbu areas are gypsum.

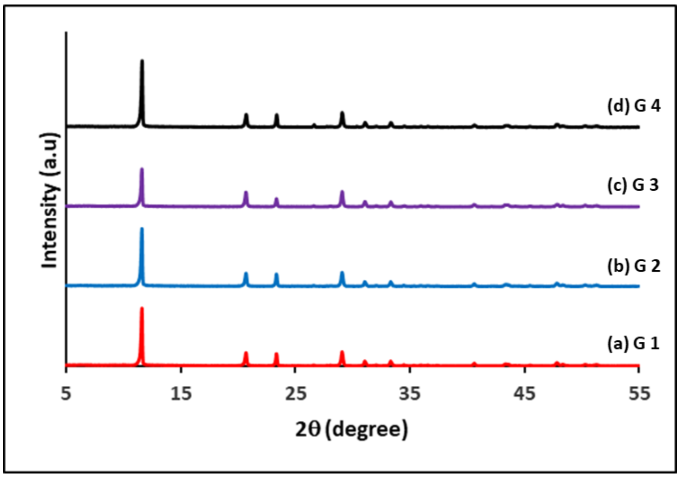

Figure 10. XRD patterns of the collected samples (G1-G4) from site no.1-4, Minhla area, Magway region.

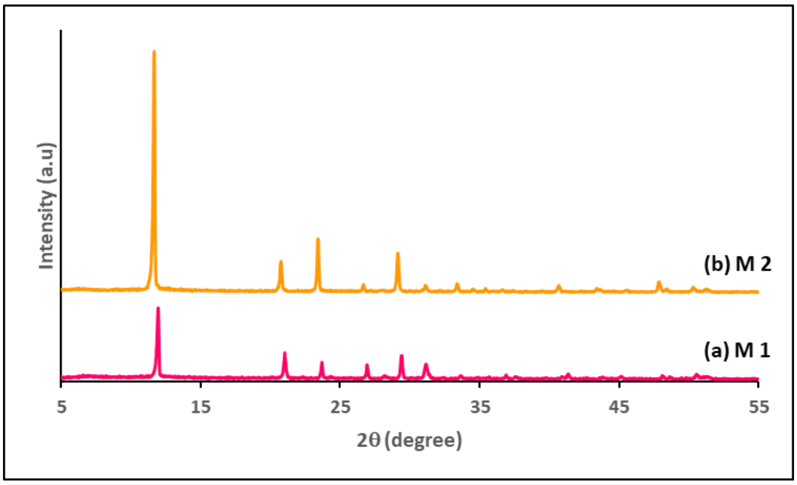

Figure 11. XRD patterns of the collected samples (M1 and M2) from site no.1 and 2, Minbu area, Magway region.

Thermogravimetric analysis (TGA)

Thermogravimetric analysis (TGA) is based on the loss of weight when a sample containing gypsum is heated. These methods are recommended when the content of gypsum is high (Jaume Porta 1993). Thus, TGA analysis was performed to observe the thermal behavior of the collected samples from different sites and these were executed using a simultaneous thermal analysis machine. The investigating temperature was from 70 °C to 900 °C with a heating rate of 20°C per minute. The experiment was performed with an alumina sample holder, and the reference maintained an inert atmosphere by purging nitrogen gas. The TGA curves of the collected samples from different sites from Minhla and Minbu areas are shown in figure 12 and figure 13. The crystal structure of gypsum is composed of layers of tightly bound Ca^{2+} and $SO4^{2-}$ ions, separated by water molecules stabilized by a network of hydrogen bonds. As observed from the TGA curves, only one stage of weight loss is noticed in figure 12 (a-d) and figure 13 (b), which occurred within in the temperature range of 200° - 300 °C. The complete dehydration of collected samples (gypsum, $CaSO_4.2H_2O$) from different sites is the loss of water molecules and corresponds to the weight loss about 20%, the result is similar with the reported research. The results indicate the transformation and crystallization of anhydrite, Ca_2SO_4 form of the gypsum, $CaSO_4.2H_2O$ (Sahadat Hossain Md,2022). On the other hand, two stages of weight loss are occurred in figure 13 (a), this is attributed to the presence of another compound.

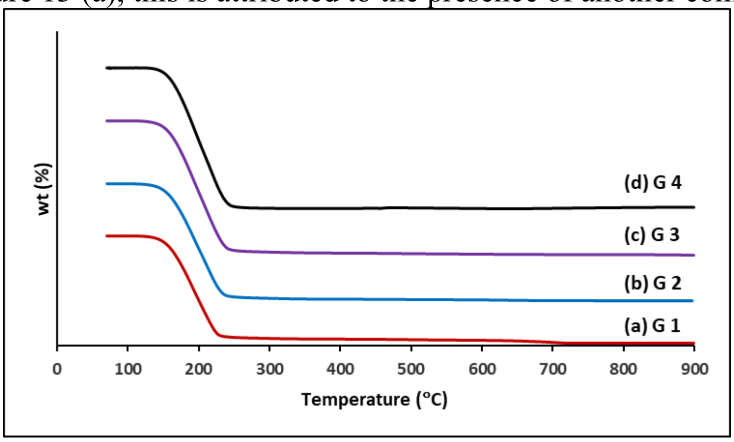

Figure 12. TGA curves of the collected samples (G1-G4) from site no.1-4, Minhla area, Magway region.

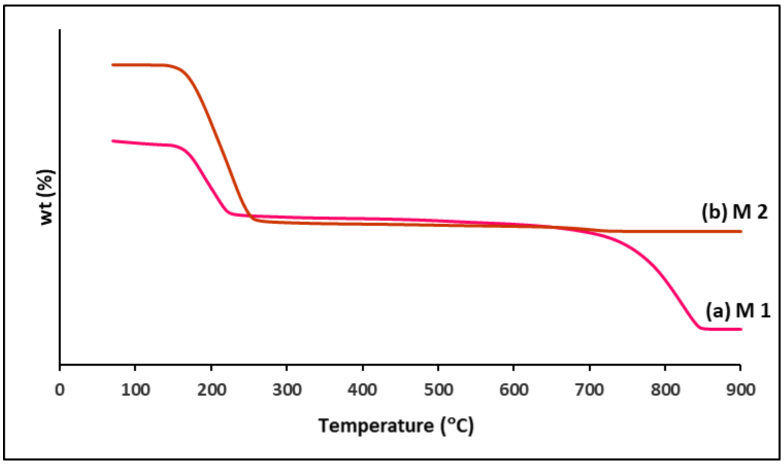

Figure 13. TGA curves of the collected samples (M1 and M2) from site no.1 and 2, Minbu area, Magway region.

Conclusions

In this report, the collected gypsum samples from the Minbu and Minhla areas were characterized by ED-XRF, XRD and TGA. Use of these analytical techniques proved to be an efficient way to identify the minerals gypsum. EDXRF study confirmed the main constituent of the collected samples are calcium, Ca and sulphur, S. In the collected samples, Ca and S contents are ranging from 61 to 67 mass % and 17 to 28 mass %, respectively. From the XRD analysis, all the diffraction peaks of the collected samples are at 2-theta values of about 11°, 20°, 23°, 29°, 31°, 33°, 40°, 47° which can be assigned to the crystal planes (020), (021), (040), (041), (-221), (220), (151) and (080) of gypsum, $CaSO_4{\cdot}2H_2O$. TGA analysis was performed to observe the thermal behavior of the collected samples from different sites and these were executed using a simultaneous thermal analysis machine. The complete dehydration of collected samples from different sites (gypsum, $CaSO_4.2H_2O$) is the loss of water molecules and corresponds to the weight loss about 20%. The combination of techniques employed in this study will greatly enhance the accuracy of detection of various minerals. The analysis techniques ED-XRF, XRD and TGA confirm that the collected samples from different sites are gypsum. Gypsum plates were noted only in the clay sequence of the area, especially in Pyawbwe Formation in Minbu and Minhla areas. They are found as disseminated clear plates with vitreous lustre under the sunshine. They are about 0.5 to 1 cm thick and 5 to 10 cm long. There are several proposed mechanisms for the formation of the gypsum veins in sedimentary rocks overlying evaporites (Gustavson.et.al,1994). These are (a) contraction of the host rock by dehydration (Richardson, W. A.1920) (b) tectonism (Forbes, B. G.1958) (c) force of crystallization (Halferdal, L. B. 1960), (Taber, S. 1916) (d) hydraulic overpressure (Shearman.et.al, 1972) (e) hydration of anhydrite to gypsum (Stewart, A. J.1979) and (f) subsidence due to dissolution of underlying evaporites (Gustavson, T. C. 1980), Goldstein.et.al, 1984). Usually, a set of the mentioned mechanisms are responsible for the veined gypsum occurrences. At Minbu and Magway areas, gypsum occurs as layers and veins in different geometrical settings. Here, we propose that the fractures where gypsum precipitated were formed due to the pressure or forces generated by crystal growth/crystallization.

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