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ORIGIN OF IRON ORE DEPOSITS IN MAYMYO FORMATION EXPOSED AROUND BAW VILLAGE, PYINOOLWIN TOWNSHIP, MANDALAY REGION, MYANMAR

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Abstract

Iron ore deposits are located around Baw village (N Latitude 21° 53'96" and E Longitude 96° 32'08"), Mandalay region, Myanmar. It lies in the western margin of the Shan Plateau within SibumasuTerrane. Rock units exposed in the area are Paleozoic rocks including Nyaungbaw Formation (Silurian age), Zebingyi Formation (early to middle Devonian age) and Maymyo Formation (middle Devonian to Permian age). Iron ores are mainly limonite and hematite with minor amounts of pyrite and magnetite. The deposit mainly forms in Maymyo Formation. Ore deposit entirely overlies on dolomite and sandstone of Maymyo Formation. Large ore boulders may reach about 15 cubic meters in size. Small nodular, concretionary iron ore and float ore also occur. In some places, these iron ores are embedded in reddish brown ferruginous sandy soil and sandy loam layers. Based on the result of borehole data, ore boulders decrease in size from south to north. This is because the fault that separates the two blocks, impounds oxidizing water and enriches iron in the hanging wall block (south), causing more concentration and thickening of the iron deposits. The occurrences of micro fossils (forams?) and ooids which are entirely or partially replaced by interlayered hematite indicate that the iron deposit is primarily of sedimentary origin probably formed at the end of Paleozoic time (Tin AungMyint, 2002). The porous and soluble nature of Maymyo Formation is the favorable place for the formation of iron deposits on Shan Plateau. Besides, chemical weathering processes leached dolomite and calcite minerals from earlier formed iron deposit, causing the increasing of iron grade in the ore as well as removing of gangue minerals from the ore in order to form the ferric iron oxides as secondary residues that are found sporadically around Baw village. Jordan et al., (2017) dated the zircon U-Pb ages of 399 Ma, for a limestone near Pyinoolwin which suggests that the age is consistent with fossil ages of the Middle Devonian Maymyo Formation. The relativity plots of the zircons suggest that the provenance has a Gondwana affinity, as the peaks of the zircons confirm the affinity with the Sibumasu Terrane.

Keywords: iron ore deposits, Maymyo Formation**,** Gondwana affinity, Sibumasu Terrane

Introduction

Location

Iron is one of the most abundant elements in the earth’s crust and few rocks are iron-free (Pettijohn, 1974). The study area is situated about 12.4 miles (20 km) south of the Pyinoolwin town. It falls in the one-inch topographic map 93C/9. The area is readily accessible in all weather.

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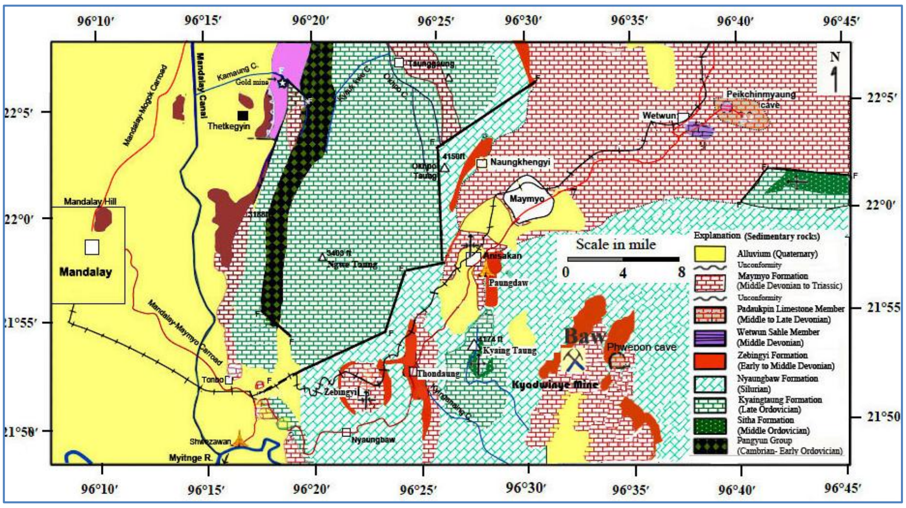


Source: Aye KoAung&Kyaw Min, 2011; Khaing Khaing San, 2005; Khin Maung Shwe, 1973; Myint Oo, 1997; Win WinKyi; 1990, Tin AungMyint, 2002; 2013; &Zaw Min Thein, 1995)***(Compiled by Tin AungMyint, 2014)***

Figure 1 Location and regional geological map between Mandalay and Maymyo (PyinOoLwin) area.

Regional Geologic Setting

Iron ore deposits around Baw village lies in the western margin of the Shan Plateau (Shan-Thai Block) within Sibumasu Terrane. The Shan- Thai Block lies to the east of the west Myanmar Terrane (aks Myanmar Plate) separated by the well-known Sagaing Fault of Win Shwe (1971). These two blocks are also separated by the "Shan Scarp Fault" or "Boundary Fault". The Shan Scarp fault runs along the western margin of the Shan Plateau and the structural features in the study area are related to this regional fault. The basement of the plateau is composed of Chaung Magyi Group of Proterozoic age. On the west of the boundary fault, the metamorphic rocks of the Mogok Belt (Searle and Haq, 1964) and some granitic intrusions are exposed. The Paleozoic sediments are exposed repeatedly in the Zebingyi, Thondaung, Kyaing Taung, Aniskan and Baw villages (Fig. 1). The study area lies mostly in the Pyintha-Aniskan plain. The strata exposed in the present study area form a south-west-dipping homocline which itself is the eastern limb of the Kyaingtaung anticline.

Method of Study

Detailed geological study of the area, classification of rock units and the occurrences of the iron deposits were carried out during the course of field study. Detailed geological data on dip and strike of the lithologic units, attitude of joints and other structural elements were measured and recorded for structural interpretation. Tape-and-compass method and bore hole data are employed to determine the thickness of iron ore deposits, the nature of deposit types and the exposed rock units in the study area. The representative ore and rock samples were taken from each bore-hole and test-pit. The collected samples were analyzed by using PXRF. Photographs and sketches were taken for some significant features.

Result

In the study area, the regional strike generally runs north-south, parallel to the regional topographic trend. It represents the eastern limb of a major anticline (Kyaingtaung anticline see Fig. 1) whose anticlinal crest is located about six miles to the west of the study area. The detailed geological map of the study area is shown in Fig. (2). Rock units are as follows.

Lithostratigraphic Units	**Geologic Age**
Alluvium	Quaternary
Unconformity	
Maymyo Formation	Mid-Devonian to Permian
Zebingyi Formation	Early to Middle Devonian
Nyaungbaw Formation	Silurian

Iron Ore Deposits at Baw and Its Environs

At Baw and around it, iron ore occurs entirely in Maymyo Formation. At least 9 iron ore deposits of considerable sizes other than Kyadwinye deposit can be recognized in the study area. These iron ore deposits are Kyadwinye deposit, Kyaukphyagyaw (G.058534), Thegon (G.065519), Pongon(East) (G.099554), Nattawtaung (G.107558), Sintheka Taung (G.112564), Nattawlay Taung (G.124575), Pawpyin (NE) (G.106570), Baw(S) (G.091514), and Kyadwinye(S) (G.069529), respectively. Among them, Kyadwinye and Kyaukphyagyaw deposits contain high iron content (50%-60% Fe). Moreover, numerous small scale iron occurrences which are economically unfeasible are found throughout the area.

Iron Ore Deposit at Kyadwinye

Kyadwinye mine is located at latitude 21˚ 51'N and longitude 96˚ 32' 20"E. In Kyadwinye, the iron deposit occurs on the Main hill (Foot wall) (3498') and mine site in lower hill (Hanging Wall) separated by Kyadwinye fault. The area coverage is about 6725640 square feet (624811.9 sq.m.). Iron ore map (Fig. 3a), cross sections and bore hole profiles (Fig.3 b & c) are shown respectively.

The thickness of iron deposit on the Main hill is only 12.8' (4m) thick. However, at the mine, the iron ore deposit is much thicker, reaching up to 70' (22m) in thickness. Field investigation shows that the mine is situated on the down thrown side of the fault. This normal fault is thought to be formed before the deposit because ore body in lower hill is much thicker than the Main hill and there is no evidence that this fault separates the ore body.

In Kyadwinye, the iron ore deposit comprises limonite and hematite with minor amount of pyrite and magnetite found in dolomite and sandstone of Maymyo Formation. The bore-hole data indicates gradual increase of limonite content with depth. This is because limonite contains hydroxide and the nearer the water table, the more limonite content increases.

The surface of the ground shows scattered light brown ferruginous gravel and larger pieces of iron ores. Iron ore occurs in different forms: as boulders, nodular masses, gravels or floats Fig. (4 a-d). The sizes of the ore boulders decrease from south to north. The biggest one is reaching up to 15 cubic meters (530cubic feet). Iron ores are not cemented together nor very firmly embedded in the sandy loam which surrounds them; neither do they form a continuous layer. Some ore boulders show dendritic tubes filled with silt resembling worm burrow tubes Fig. (4b).

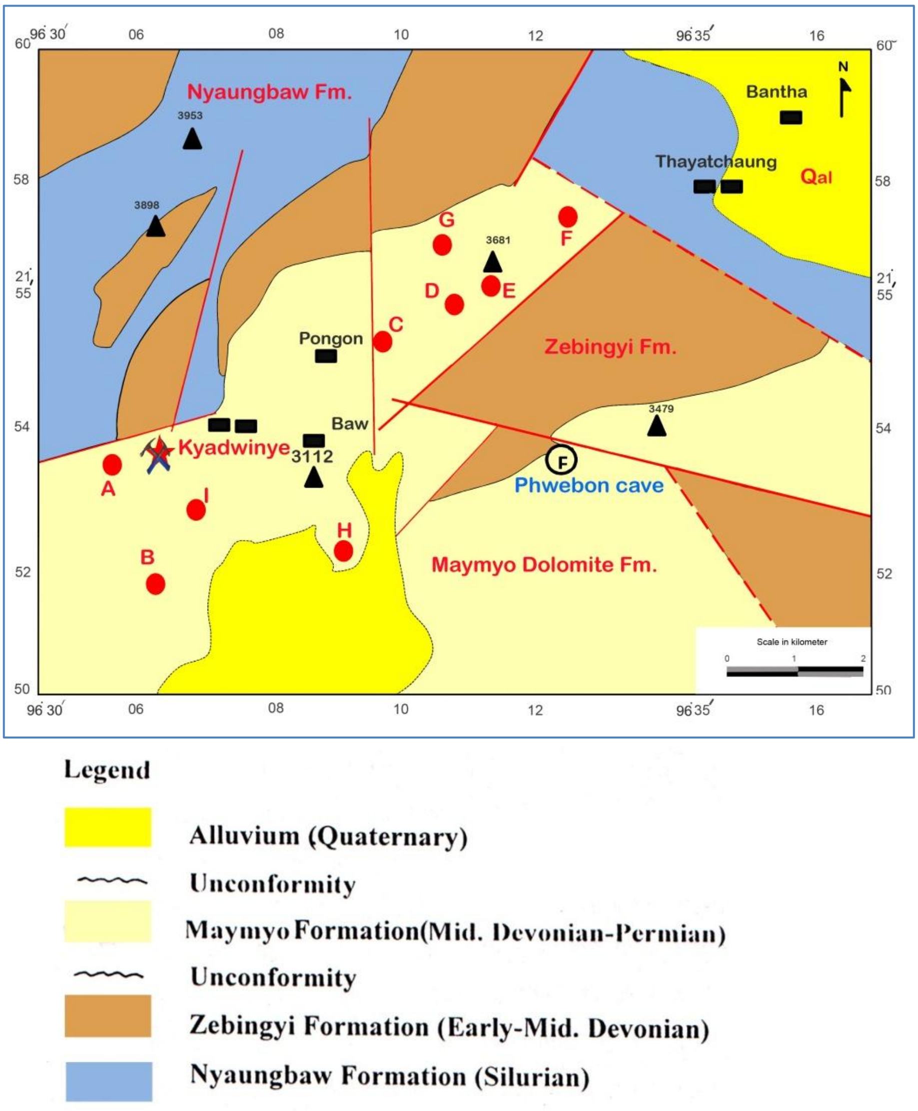


Figure 2 Geological map of the Baw area (Win WinKyi, 1990 & Tin AungMyint, 2002)

Field investigation shows that the thickness of the ore body in the lower hill is from 1.6' (0.5m) to 70' (22m). Although the iron ore deposit is nearly parallel to the bedding planes of the underlying rocks, the iron ore in bedding is hardly noticeable. The boundary between the iron ore body and Maymyo Formation is undulatory mostly (Fig.4 d). Thus, the iron ore occurs as filling in the cavities and hollows in Maymyo Formation. This fact points out that iron ore deposit unconformably overlies on Maymyo Formation.

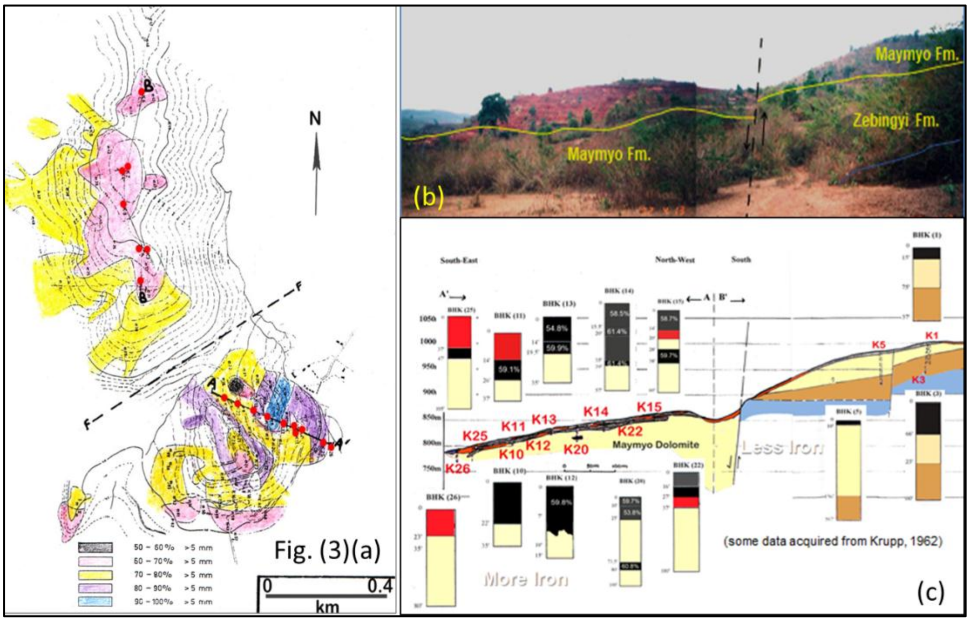


Figure 3 (a) Iron ore and bore hole location map, (b) Panaromic view of the mine area and (c) cross section passing through the Bore holes of (Fig. a) with their Fe content. (Tin Aung Myint, 2002) (some data acquired from Krupp, 1961-1962)

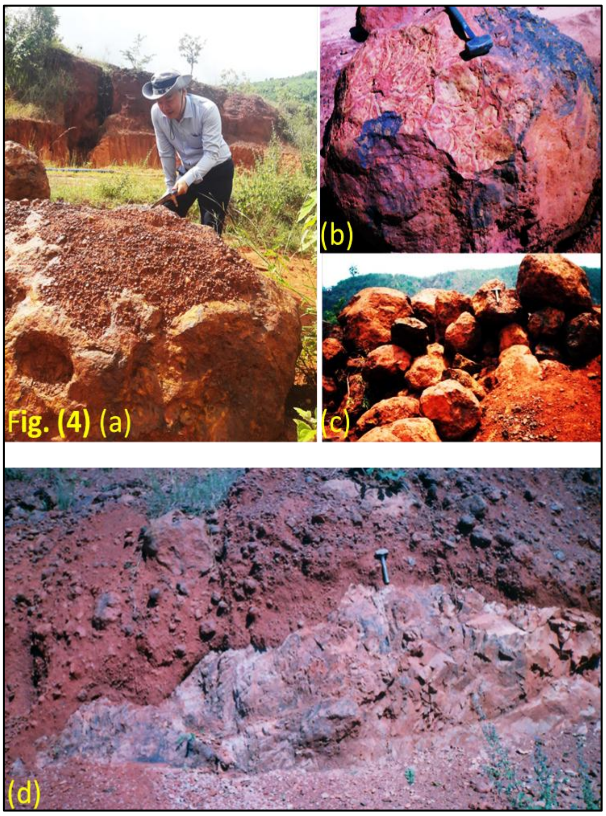


Figure 4 (a) Large ore boulder in mine, (b) Dendritic patten like tubes filled with sandy silt in the area, (c) Various sizes of iron ores and (d) Iron gravels mixed with loam on Maymyo Formation.

The ore is trucked to the No.1 Iron and Steel Plant at Aniskan located about 16 km west of Pyinoolwin. The plant produces pig iron, steel billet, rounded bars and steel grinding balls (Soe Win, 1994). Although Krupp and BGD (1961-62) gave a reserve of 3 million tons, the estimated iron ore reserve is less than 2 million tons with average iron content of 58.5% (Tin Aung Myint & Mi Mi Ko, 2004).

Other Iron Ore occurrences around Baw

Around Baw, iron ore deposits unconformably overlie on the Maymyo Formation. These deposits are embedded in ferruginous sandy soil layer and sandy loam layer. The localities of iron occurrences and their detailed descriptions are shown in Fig (2) & Table (1).

There are altogether 9 occurrences that contain iron content of 21.33% to 61.38%. Thus, it can be correctly interpreted that Kyaukphyagyaw will be another alternative mining site of iron ore when the Kyadwinye Mine is exhausted.

Table 1 Ore Reserve and chemical analyses of small iron ore occurrences around Baw

No	Code	Work Site	Area (Sq.m)	Thickness (m)	Mineral Percent			Sp.Gr.	Category	Ore Reserve	
					FeO%	SiO_2%	Al_2O_3%			Total	>5mm
1	A	Kyaukphyagyaw (G.058534)	38100	0.9	61.38	1.27	8.66	4.18	P_3	11000	9000
2	B	Thegon (G. 065519)	134112	1.2	39.03	26.51	12.72	3.12	P_3	40800	34500
3	C	Pongon (East) (G.099554)	51816	1.8	26.10	45.71	12.43	3.47	P_4	33800	26400
4	D	Nattawtaung (G.107558)	36576	2.7	32.33	37.98	11.03	3.66	P_4	22400	19600
5	E	Sinthekataung (G.112564)	32004	1.7	26.25	45.27	10.09	3.29	P_4	15800	12200
6	F	Nattawlaytaung (G. 124575)	45750	1.5	29.15	39.80	13.57	3.86	P_4	24600	24400
7	G	Pawpyin (Northeast) (G.106570)	28956	2.3	24.49	46.78	5.63	3.82	P_4	24300	20400
8	H	Baw (South) (G.091514)	41148	1.2	21.33	46.81	11.88	3.40	P_4	15500	13700
9	I	Kyadwinye (South) (G.069529)	16764	1.0	27.28	31.71	18.81	3.25	P_4	5300	4600

(**Source:** DGSE, 2000 & Tin Aung Myint, 2002)

Discussion

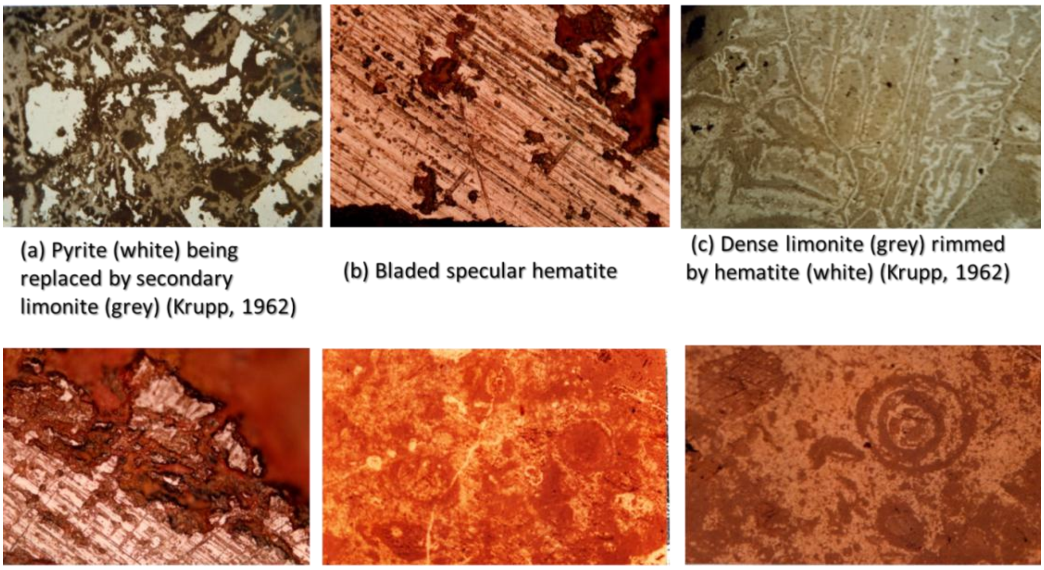
Origin

Mineral Paragenesis and Texture

Ore microscopic study reveals the most probable mineral paragenesis of iron ore at Baw. As shown in Fig (5) pyrite (white) is replaced by limonite (grey). Replacement is the result of a surface chemical reaction, hence, any channel between grains or through grain is a prime site for initiation of the replacement process (Craig and Vaughan, 1981). In the early stages of the process, replacement may be readily identified because much of the original phase (pyrite) remains and the original grain boundaries and fractures are still visible. Therefore, this appears to suggest that pyrite formed earlier than limonite and hence, limonite is thought to be considered as secondary replacement mineral. The resulting boundary between the replaced (pyrite) and the replacing mineral (limonite) is commonly sharp and irregular (corroded texture). The replacement features in which pyrite has been pseudomorphed by dense limonite (grey) and boxwork hematite (white). The open void 'boxwork' texture is essentially composed of cellular crisscross laths of hematite, showing the evidence of replacement. Judging upon these replacement textures, the most priority is pyrite, and second phase is not only hematite but also limonite. Therefore, it is also important to note that iron ore deposit in Kyadwinye may have more than ore paragenetic position.

Deposit Styles and Types

Field investigation shows that iron ore unconformable overlies on the Maymyo Formation and it is nearly parallel to the underlying beds. Peloids and some distorted ooliths occur in iron slide (see Fig. 5). Ooids and peloids are typically replaced by limonite and hematite. Some micro fossils (forams?) are also observed and partially replaced by hematite. It could be stated that iron ore in Baw was primarily sedimentary origin. Although the ores are found as sub-parallel to the bedding, they form rarely as layers. Despite them, the ores occur mostly as boulders and nodular masses. This is because the chemical weathering processes leached siliceous and carbonated minerals from the bedded iron deposit, resulting in an up grading of the iron content.



(a) Pyrite (white) being replaced by secondary limonite (grey) (Krupp, 1962)

(b) Bladed specular hematite

(c) Dense limonite (grey) rimmed by hematite (white) (Krupp, 1962)

(d) specular hematite with boxwork texture

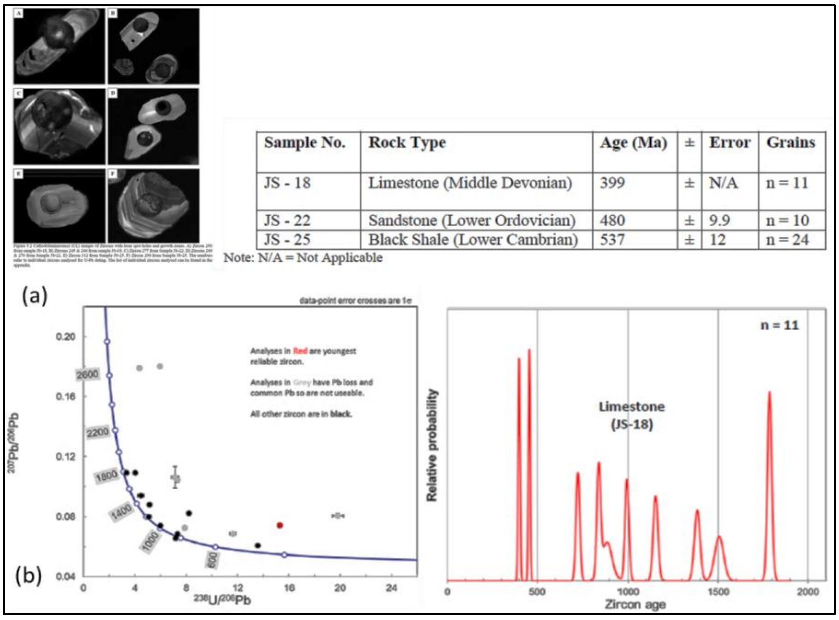
(e) Ooids, peloids and micro fossils partially replaced by hematite and limonite

(f) Ooids and fossil fragments replaced by hematite

Figure 5 Some photomicrographs of iron ores in Maymyo Formation around Baw Village.

Geochronology

The Devonian is a period of Earth's history that went through radical change both physically and chemically. In this study, Laser Ablation Inductively Coupled Mass Spectrometry (LA-ICPMS) was used to determine detrital zircon ages within the black shales, sandy limestone and shaly limestone from the Lower Cambrian, Lower Ordovician and Middle Devonian and Middle to Upper Devonian in Myanmar together with scientists from Tasmania University, Australia. The zircon U-Pb ages for sample JS-18 which is a limestone, was aged at 399 Ma, which suggests that the age is consistent with fossil ages of the Middle Devonian Maymyo Formation. Sample JS – 22 is a sandstone from the Lower Ordovician Naungkhangyi group which was ages at 480.3 Ma ± 9.9 Ma. Sample JS-25 which is a black shale, is aged at 537 Ma ± 12 Ma (Jordan Sheppard et al., 2017) (Fig. 6). This suggests the U-Pb zircon age of the rock to be from Lower Cambrian Ngwetaung Group. The relativity plots of the zircons suggest the provenance has a Gondwana affinity, as the peaks of the zircons confirm the affinity with the Sibumasu Terrane. This indicates both the source of the detrital zircons, and the source of the sediment



Sample No.	Rock Type	Age (Ma)	±	Error	Grains
JS - 18	Limestone (Middle Devonian)	399	±	N/A	n = 11
JS - 22	Sandstone (Lower Ordovician)	480	±	9.9	n = 10
JS - 25	Black Shale (Lower Cambrian)	537	±	12	n = 24

Note: N/A = Not Applicable

Figure 6: (a) Cathodoluminesence (CL) images of Zircons with laser spot holes and growth zones and (b) Concordia diagram and probability curves of ratios of 207Pb / 206Pb vs. 238U/ 206Pb for sample **A)** JS-18 silty limestone from Middle Devonian Maymyo Formation. (Source: Jordan et al., 2017)

Summary and Conclusion

The study area is situated in Pyinoolwin Township, some 12.4 miles (20 km) south of the town. Baw is located at latitude 21° 53'96"N and longitude 96° 32'08"E. It covers an area of approximately 40.8 sq. miles (106 sq. km). Actually, the present study area forms a south west dipping homocline which itself is the eastern limb of Kyaingtaung anticline located on the western margin of the Shan Plateau. Rock units exposed in the area are Paleozoic rocks including Nyaungbaw Formation (Silurian age), Zebingyi Formation (early to middle Devonian age) and Maymyo Formation (middle Devonian to Permian age).

Iron mineralization occurs mainly on dolomite and sandstone of Maymyo Formation. It is mainly composed of hematite and limonite with minor amounts of pyrite and magnetite. Iron ores occur in different forms as boulders, nodular masses, iron gravels and floats which are not cemented together or very firmly embedded in the sandy clay (loam) that surround them, neither do they form a continuous layer. The thickness of the iron deposit varies from 4 to 22 meters in mine site. Large ore boulders may reach about 529.7 cubic feet (15 cubic meters) in size. According to bore hole data, the size of the ore boulders decreases from south (lower hill) to north (Main hill). This is because the fault, that separates these two blocks, impounds oxidizing water and enriches iron in the hanging wall block, causing more concentration and thickening of the deposit. The deposit style is primarily of bedded sedimentary origin probably formed at the end of Paleozoic as the presence of micro fossils (forams?) and ooids which are entirely or partially replaced by interlayered hematite as the iron is essentially and completely precipitated as ferric oxide or may replace calcium carbonate shells or ooids. Moreover, readily soluble and porous natures of Maymyo Formation are the favorable site to concentrate the formerly formed bedded iron deposit. Therefore, the removal of soluble constituents and concentration of the insoluble ones must have been enormous. These conditions, limestone formation will be slowly dissolved by chemical weathering, leaving the insoluble iron oxides as residue. As bed after bed of limestone disappears, the iron oxide of each bed persists. In this way, residual iron concentration was happened. The source was believed to be derived from the considerable iron ore in non-aluminous dolomite and ferruginous sandstone of the lower stratigraphic horizons of the plateau limestone. The origins of other iron occurrences around Baw are probably the same origin of Kyadwinye deposit.

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