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Zeolite Mineralization Prospect within the Basalts of Tim-Kwalla, Jos Plateau North Central Nigeria

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ABSTRACT: *Detailed geological mapping of part of Kwolla Sheet 211 NE on scale 1:50,000 was carried out. Mapping revealed that Tim-Kwalla Basalts occur as pyroclastics in form of boulders in a ring pattern and also as "flow" basalts as seen along stream channels. Three petrographic rock types are presented in the area; The Granite-gneiss, the Biotite granite and the Newer Quaternary basalts. Some major oxides were determine through XRF geochemical analysis which include SiO_2, Al_2O_3, K_2O, Fe_2O_3 and CaO. Plots from the major oxides suggest the Tim-Kwalla Basalts to be of pre-plate collision petrogenetic source having high Fe tholeiitic Basalts. XRF geochemical of the white crystalline substance revealed the presence of Ca-rich zeolite in form chabazite and phillipsite*

I. INTRODUCTION

The Jos Plateau Basalts are subdivided into two subtypes based on their textures and mode of occurrences viz Newer and Older Basalts which occur as cones and lava flows, mainly built of basaltic scoria and pyroclastics (Lar and Tsalha, 2005). The Newer Basalts occupy nearly 150km^2 in the Western and Southern Jos Plateau. They also extend towards the Kafanchan area and Southwards down to the Shimankar valley. They occur as cones and lava flow characterized by steep-sided central craters raising a few metres above their surroundings. The Newer Basalts cones are aligned in NNW-SSE direction, corresponding to the trend of dolerite dykes (Mcleod et al, 1971). The Newer Basalts are mainly vesicular, riddled with small cavities attributing to escaping gases and water vapour. (Tsalha et al, 2014).

Zeolites are a group of basic, hydrous aluminosilicate minerals. They possess an open alumino-silicate framework structure containing channels filled with water molecules and cations. The water molecules are easily dehydrated by heating and re-hydrated in the air without significant changes of the framework. The cations are usually exchangeable at low temperature below 100^{o}c (Iijima,1980).

Natural zeolites occur as an alteration product of glass of a volcanic or impact origin, amorphous clay and allumino-sillica gel. They replace crystalline materials such as nepheline, plagioclase, precursor zeolite, and smectite. Also, they precipitate in cavities and veins from hot or cold solution. However, fine-grained glass fragments are the most important raw material of natural zeolites for almost all types of occurrence, because of their high reactivity and similar chemical composition to certain zeolites. (Iijima, 1980).

Formation of zeolite species is influenced by various factors. Chemical composition of original material of the zeolite and composition of host rocks primarily control zeolite species particularly at low temperature. Zeolites in alkaline rocks are of basic species except analcime and faujasite, while those in acidic rocks are "acidic" and "intermediate" ones (Iijima, 1980)

The major benefit of natural zeolite (crushed natural zeolite) is that all applications enable environmental solutions and cost savings. Natural zeolite is stable, solid, and totally natural and can be introduced into many fields (e.g Agriculture, water filtration and effluents treatment, mining, etc.) (Abaa, 2006). Industry has mimicked some of the natural zeolites, and formed many new ones targeted towards very specific purposes. Many of these are used in the petrochemical industry to "crack" or breakdown various raw materials to form specific chemicals like gasoline (Abaa, 2006).

II. STUDY AREA

Tim-kwalla lies on Kwolla map sheet 211 NE which covers part of Quaan-Pan and Shendam L.G.As of Plateau State Nigeria (fig. 1). The area is linked with motorable roads and numerous foot paths. The area is situated in the tropical zone (hot and humid climate). Harmattan winds cause the coldest weather between December and February. The warmest temperatures usually occur in the dry season months of March and April. Vegetation falls within the northern guinea savannah zone of Nigeria.

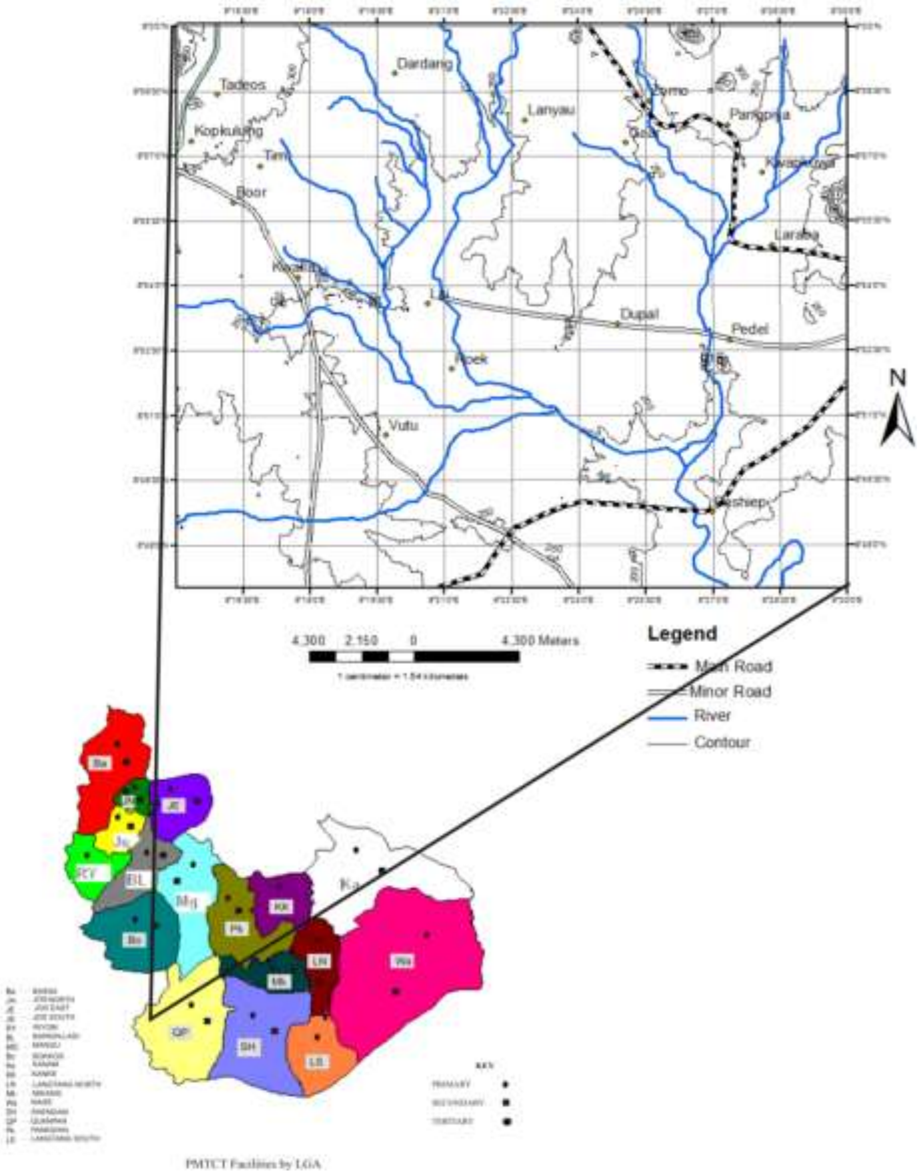

Fig. 1: Map of Plateau State showing the study area

III. MATERIALS AND METHODOLOGY

In order to carryout effective research work, materials such as topography map (Kwolla Sheet 211 NE) on scale 1:50,000 was used, geological hammer, measuring tape, global positioning system (GPS), sample bag, camera were used on the field. Methods and procedures that were adopted include; geologic traverses, rocks observation and identification, measurements, photographing and samples collected with were tied to their coordinates. Fifteen basaltic rocks were collected and the crystalline substance in the vesicles of the basalts were scratched as samples and subjected to XRF analyses.

Pulverization:

The samples were pulverized (grind to fine powder) using target pulverizing machine (planetary micro mill pulverisette 7). The ground samples were ensured to pass 150 micro mesh sieves. This was to ensure homogeneity of the samples.

Pelletization:
5g of the pulverized sample was weighed into a beaker, 1g of binding aid (Starch soluble). The mixture was thoroughly mixed to ensure homogeneity, which was pressed under high pressure (6 “tone”) to produced pellets; labeled and package ready for the analysis.

***Procedure of the analysis*:**
Energy Dispersive x-ray fluorescence (EDXRF) spectrometer of model “Minipal 4” was used for the analysis.
The pellets were carefully placed in the respective measuring positions on a sample changer of the machine. The following condition sets were made as the machine was switched on.

- Elemental composition determination
- Nature of the samples to analyzed as press powder (pellet)
- The current used as 14kv for major oxides, 20kv for the trace elements/rare earth metals.
- Selected filters were “kapton” for major oxides, Ag/Al-thin for the trace elements/rare earth metals.

The selection of filters was guided by a given periodic table used for elemental analysis. Time of measurement for each sample was 100 seconds and the medium used was air throughout.
The machine was then calibrated by the machines gain control, after which the respective samples were measured by clicking the respective positions of the sample changer.
LOI was determined gravimetrically by heating 1g of the powdered sample in a cleaned weighed crucible at 1000^oc. After which the crucible and the content was weighed to get the difference in weight before and after heating.
LOI = (a-b/1) x 100% = H_2O^+
Where a = weight of crucible + 1g of the sample before heating
b = weight of crucible + 1g of the sample after heating.

Geology of the area
Three petrographic rock types were identified in the study area: The Granite-gneiss, the Biotite granite and the Newer Quaternary basalts. The Granite-gneiss represents the Precambrian Basement Complex which underlines the entire area (fig. 2).

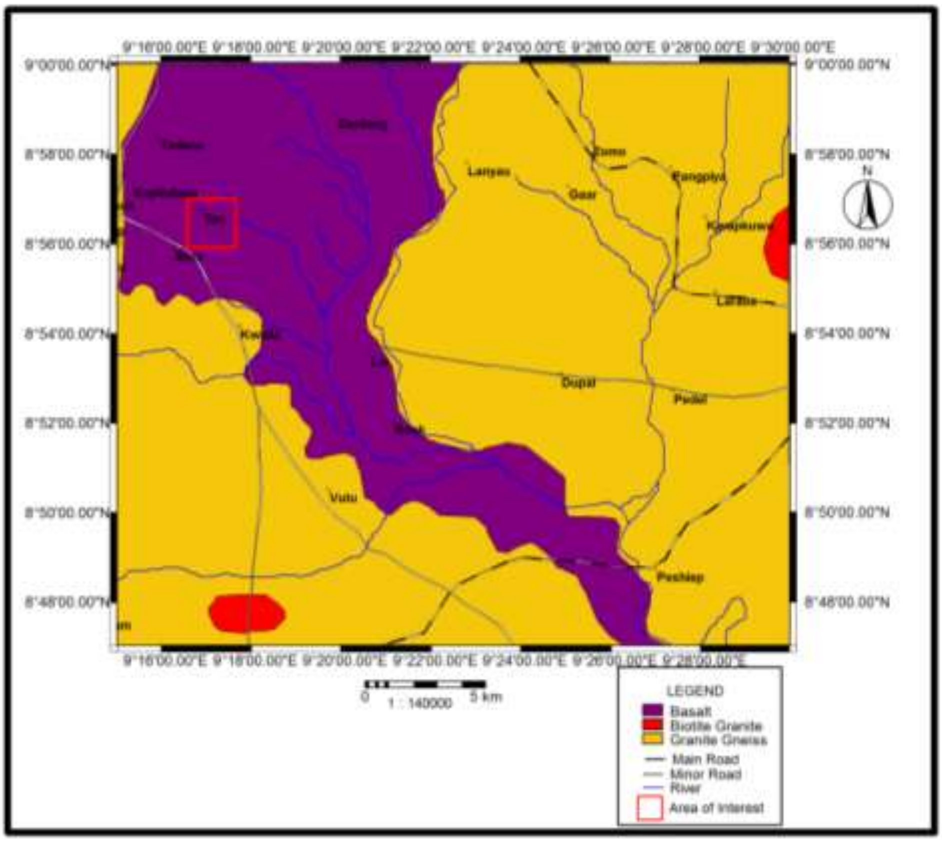

Fig. 2*:* Updated Geological map of the study area

The Biotite granite represents the Jurassic Younger Granite of the Jos Plateau. The biotite granite occur at Kurgwi hill around the South-western part of the area. It also outcrops at Kwapkuwa, North-eastern part of the area.

IV. RESULTS AND DISCUSSION

The Newer Quaternary Basalts stretches through the area in a NNW-SSE direction with a wider range of about 8-10km in the North western part, and narrows down to about 1 – 2km towards the south – eastern part of the area. The basalts generally occur as pyroclastic bounders scattered but usually tend to take a ring shape range with a more or less plain centre. The boulders varies in shape and sizes, some could be about 1- 3m in diameter (Plate 1 & 2). They are mainly vesicular, spherical, ellipsoidal, cylindrical and irregular in shapes and dark in colour. The slightly vesicular ones are mostly fine grained in texture and dark to dark-gray in colour.
At Gogot locality (N08^0 56' 21", E09^0 16'59"), there were occurrences of pyroclastic tuffs of tiny fragments, randomly scattered and white in colour within the basalts.

a) b) c)

Plate 1: Basalt boulders of various sizes

a) b)

Plate 2: Basalt showing vesicles filled with crystalline substances

Table 1: Major Oxide Geochemistry for Rocks samples

LOCALITY	SAMPLE ID	SiO2 (%)	Al2O3 (%)	SO3 (%)	P2O5 (%)	Na2O (%)	K2O (%)	CaO (%)	MgO (%)	TiO2 (%)	Fe2O3 (%)	MnO (%)	H_2O^+ (%)
Tim N08°56'35" E09°16'30"	**SAMPLE A**	44.90	16.20	0.04	-	1.07	0.77	12.61	3.47	2.55	12.30	0.10	6.98
Tim-Goejing E09° 16' 39"	**SAMPLE B**	44.70	15.90	-	-	0.90	0.65	9.28	2.01	2.99	17.85	0.42	4.80
Tim-Tugul N08°56'56"	**SAMPLE C**	46.90	19.10	-	-	0.94	0.54	8.00	1.64	2.75	16.31	0.18	3.00
Gogot N08° 56' 21" E09°16'59"	**SAMPLE D**	45.50	16.20	0.02	-	1.02	0.63	10.33	1.78	2.89	16.00	0.19	5.40
Voershik N08°58'57" E09°16'38"	**SAMPLE E**	44.00	15.40	0.03	-	1.00	0.45	11.26	1.88	2.70	17.54	0.18	6.21
Gogot B N08° 56' 21" E09°16'59"	**SAMPLE F**	19.90	6.70	0.02	-	0.01	0.60	42.21	0.44	1.39	2.60	0.10	25.90
Goeragas N08°55'30" E09°15'04"	**SAMPLE G**	47.60	18.10	-	-	1.10	0.67	8.84	1.55	2.74	15.88	0.19	3.32
Kopmoejak N08°56'24" E09°17'44"	**SAMPLE H**	42.80	16.60	0.03	-	0.87	0.60	11.25	1.76	2.94	18.36	0.38	6.79
Kopmantung N08°55'18" E09°17'05"	**SAMPLE I**	43.90	16.00	-	-	0.90	0.60	10.73	2.12	2.66	15.56	0.18	6.91
Goepia N08°59'28" E09°15'40"	**SAMPLE J**	43.70	14.90	-	-	0.90	0.51	9.00	1.58	2.75	20.38	0.19	5.72
Gaar N08°55'13" E09°17'47"	**SAMPLE K**	49.50	20.10	-	-	1.02	0.70	5.86	0.98	2.72	15.67	0.23	2.88
Poeship N08°48'47" E09°26'07"	**SAMPLE L**	46.80	19.50	-	-	0.98	0.47	7.80	1.22	2.69	15.87	0.20	4.42
Gogotkum N08°54'57" E09°16'25"	**SAMPLE M**	46.30	19.00	-	-	1.01	0.68	7.70	1.25	2.74	15.80	0.20	5.30
Yitlaar N08°58'11" E09°17'26"	**SAMPLE N**	42.30	15.20	-	-	0.87	0.45	15.28	2.10	2.73	10.05	0.17	10.83
Kwa N09°01'12" E09°15'50"	**SAMPLE O**	46.40	19.90	-	-	1.01	0.68	9.45	1.49	2.82	12.44	0.14	5.65

NOTE: Sample F is volcanic tuff

SiO_2
$Si0_2$ value ranges between 19.9% to 49.50% with an average value of 43.65% among the Tim-Kwalla basalts. Sample F is a volcanic tuff with the lowest value of 19.90%. The average value of 43.65% is slightly lower than the standard value of the 50%.

Al_2O_3
The value of Al_20_3 ranges between 6.70% to 20.10% with an average value of 16.5%. Sample F recorded the lowest value of 6.70% among the Tim-Kwalla basalts. The average value of 16.5% is slightly greater than the standard value of 15%.

K_2O
The K_2O value ranges from 0.45% to 0.77% with sample E and sample N recording 0.45% lowest value and sample A recording the highest of 0.77% within the Tim-Kwalla basalts. However, the average value of K_2O within the Tim-Kwalla basalts is 0.6% which is slightly above the 0.55% standard average value.

Fe_2O_3
The value of Fe_2O_3 ranges from 2.60% to 20.38%. the average value is 14.84%, while sample F recorded the lowest value of 2.60% within the Tim-Kwalla basalts. The average value of 14.84% is greater than the standard average value of 6%.

CaO
The value of CaO ranges from 5.86% to 42.21% with the Tim-Kwalla basalts with sample F the volcanic tuff recording value of CaO is 11.31%.

Geochemistry of the Sampled Rocks

Table 2: Major Oxides (%)

SAMPLES ID	SIO2 (%)	A1203 (%)	SO3 (%)	P205 (%)	Na20 (%)	K2O (%)	CaO (%)	MgO (%)	TIO2 (%)	Fe203 (%)	MnO (%)	H2O+ (%)
SAMPLE	23.28	4.12	-	-	0.02	0.78	40.10	0.20	2.35	3.66	0.20	19.00

Table 3: Trace Elements/Rare Metals (ppm)

ELEMENT	SAMPLE
Ag	<0.001
As	0.020
Au	<0.001
Ba	0.200
Bi	<0.001
Br	<0.001
Cd	<0.001
Ce	<0.001
Co	<0.001
Cr	<0.001
Cs	<0.001
Cu	<0.061
Eu	<0.200
Ga	<0.001
Ge	<0.001
Hf	<0.001
Hg	<0.001
In	<0.001
Ir	<0.001
La	<0.001
Lu	<0.001
Mo	<0.001
Nb	<0.001
Ni	<0.005
Os	<0.001
Pb	<0.210
Pd	<0.001
Pr	<0.001
Pt	<0.001
Re	<0.001
Rb	<0.001
Sb	<0.001
Sc	<0.001
Se	<0.001
Sn	<0.001

Sr	<0.340
Ta	<0.001
Th	<0.001
Tl	<0.001
U	<0.001
V	<0.020
W	<0.001
Y	<0.001
Yb	<0.020
Zn	<0.048
Zr	<0.087

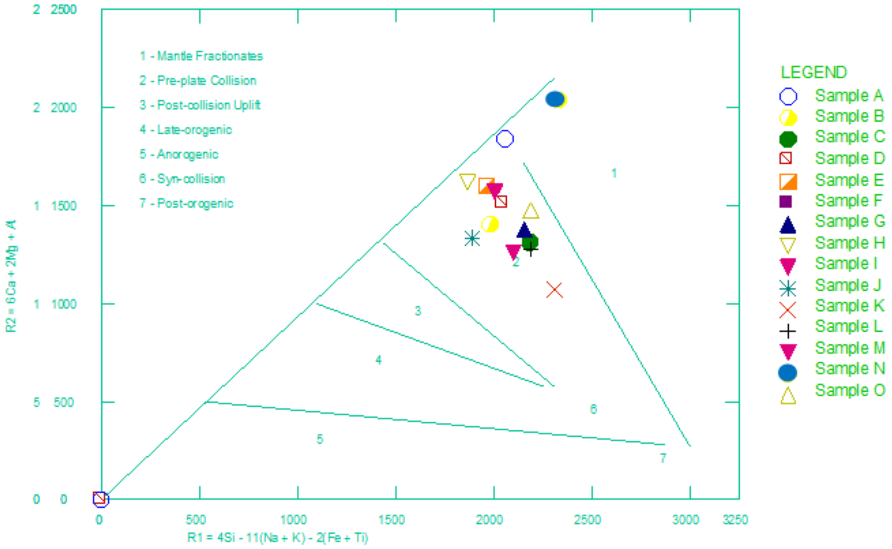

Fig. 3: $R_1 - R_2$ binary plots after (Batchelor and Bowden, 1985) to interpret the petrogenesis of the Tim-Kwalla basalts.

R_1: 4Si – 11(Na + K) – 2 (Fe + Ti).
R_2 : 6Ca +2 Mg + Al).
Samples A, B, C, D, E, F, G, H, I, J, K, L, M, and O fall within 2 on the binary plot, while sample N falls within 1.
Therefore, the Tim-Kwalla basalts belong to the Pre-plate collision source except for sample N which belongs to the mantle Fractionates.

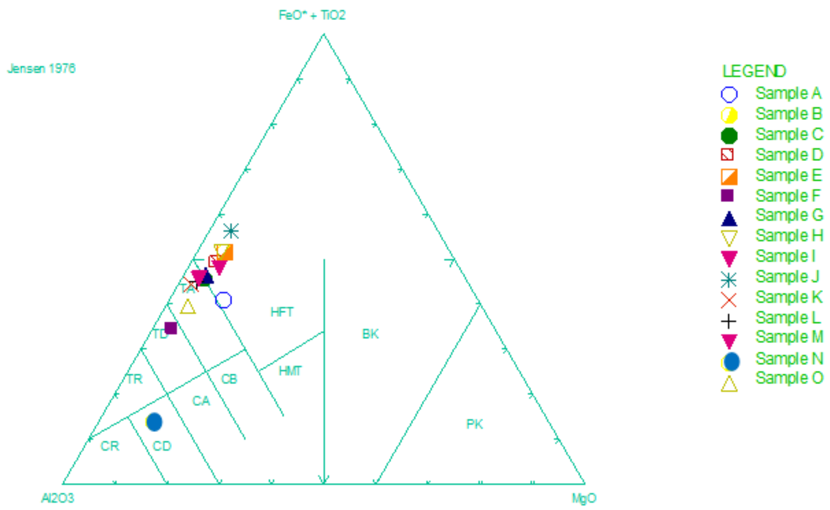

Fig: 4: AFM Ternary (cation percent; Jensen, 1976) plot for Tim-kwalla basalts. HFT – High Fe tholeiite; HMT = High Mg tholeiite; BK basaltic komatite; PK = peridotitic komatite; T = tholeiite; C = calc-alkaline, B = basalt, D = dacite, R = rhyolite).

Samples A, B, C, D, E, G, I, J, K, L, M and O falls within High Fe tholeiite, while sample H and F fall within TD (Tholeiitic dacite) and sample N falls within CD (Calcic dacite) on the AFM Ternary plot. This shows the Tim-Kwalla basalts are mostly High Fe tholeiites except sample N which is more of Calcic dacite.

Plots from crystalline substance analysis results

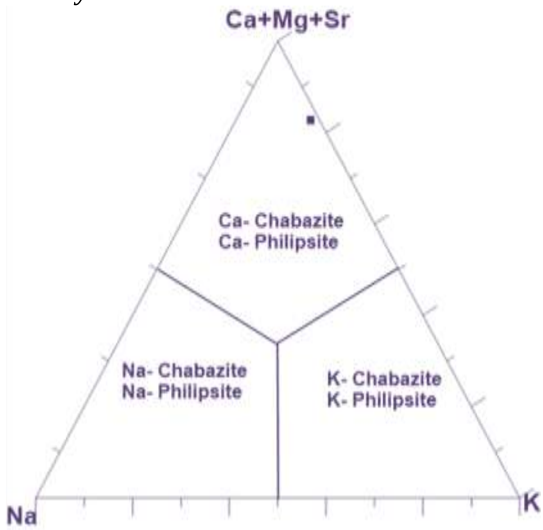

Fig. 5: Classification plot for zeolite (after Weisenberger and Spurgin, 2009). Sample classified under Chabazite, depleted in Na, and plot closer to Ca+ Mg + Sr. thus less enriched in K.

The above plot confirms the fact that CaO has higher values than Na_2O and K_2O from the geochemistry of the Tim-Kwalla Basalts.

V. CONCLUSION

Tim-Kwalla basalts occur as pyroclastics in form of boulders of different sizes. Although the boulders are scattered, they tend to occur in ring form. The pycroclastics form contain white crystalline substance as inclusions in their vesicles. Geochemical analysis revealed the Tim-Kwalla basalts to be high Fe tholeiitic alkaline basalts. Plots of the geochemical analysis of the crystalline substances indicates the presence of zeolite in form of Ca-rich chabazite and philipsite. The zeolites mineralization within the Tim-Kwalla basalts is the Ca zeolites (Ca-chabazite and Ca-philipsite).

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