International Symposium on
GEOLOGY AND ENVIRONMENT
31 January - 2 February 1996

STRATIGRAPHY OF THE MAE MOH MUD ROCKS : IMPLICATION FOR TERTIARY LACUSTRINE ENVIRONMENTS, NORTHERN THAILAND (A SHORT NOTE)

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Mud rocks from 12 boreholes in the Tertiary Mae Moh Basin (Figures 1 and 2), Lampang, northern Thailand, were studied using X-ray diffraction, scanning electron microscope, petrographic, and chemical methods. Tlhe basin is surrounded by Triassic sedimentary rocks and Permo-Triassic volcanic/volcaniclastic rocks, along with some Permian carbonate rocks and Pleistocene basalt. The Mae Moh mud rocks include overburden between the J and K lignite seams and interburden between the K and Q lignite seams (Figure 3), with average thicknesses of 70 m and 25 m, respecitively. Based on lithological and geophysical data, the interburden can be subdivided into three units: dominantly brown, somewhat fissile, claystone in the upper part; greenish gray claystone interbeded with sandy claystone, silty sandstone, and silty claystone in the middle part; grey to brown claystone with some carbonaceous material in the lower part. The overburden has two units: an upper brown claystone with intraformational conglomerate; a lower greenish brown clayey to sandy siltstone. The overburden mud rocks are chiefly quartz, calcite, and clay minerals, with some gypsum and siderite. The interburden mud rocks are gypsum, dolomite, and chlorite.

This study has indicated a new method regarding the application of clay mineralogy and geochemistry to the evolution of the Mae Moh Basin. Petrographic and field investigations indicate that rhythmic lamination of fine-grained clastic rocks (claystones and siltstones) formed as a result of contrasts in mineralogy rather than of grain sizes. X-ray diffraction and scanning electron microscope (Figure 4) investigations (Roongsa wang, 1995) support the occurrence of several clay types:

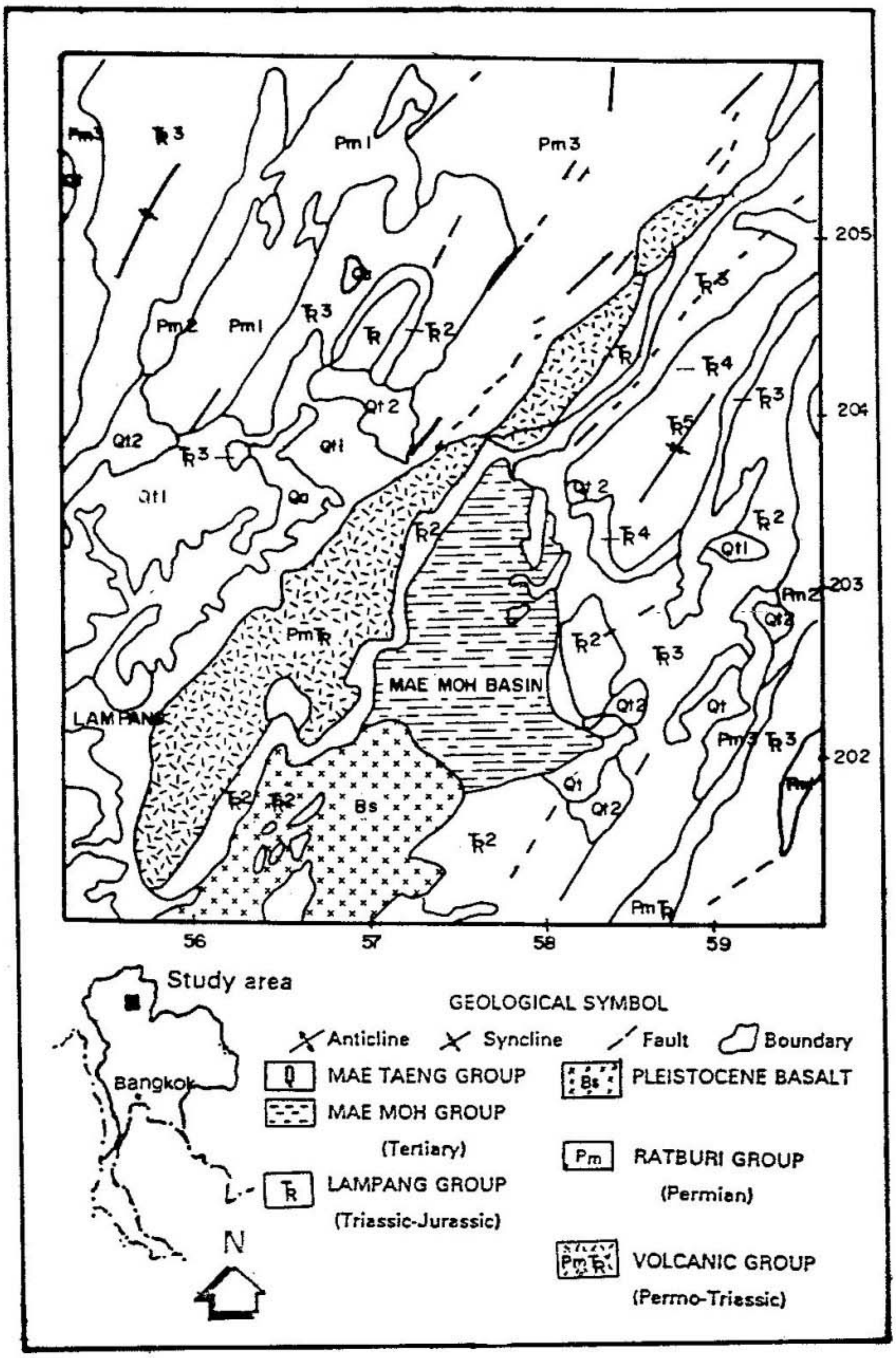

Figure 1 Regional geology surrounding the Mae Moh Basin; (after Electricity Generating Authority of Thailand)

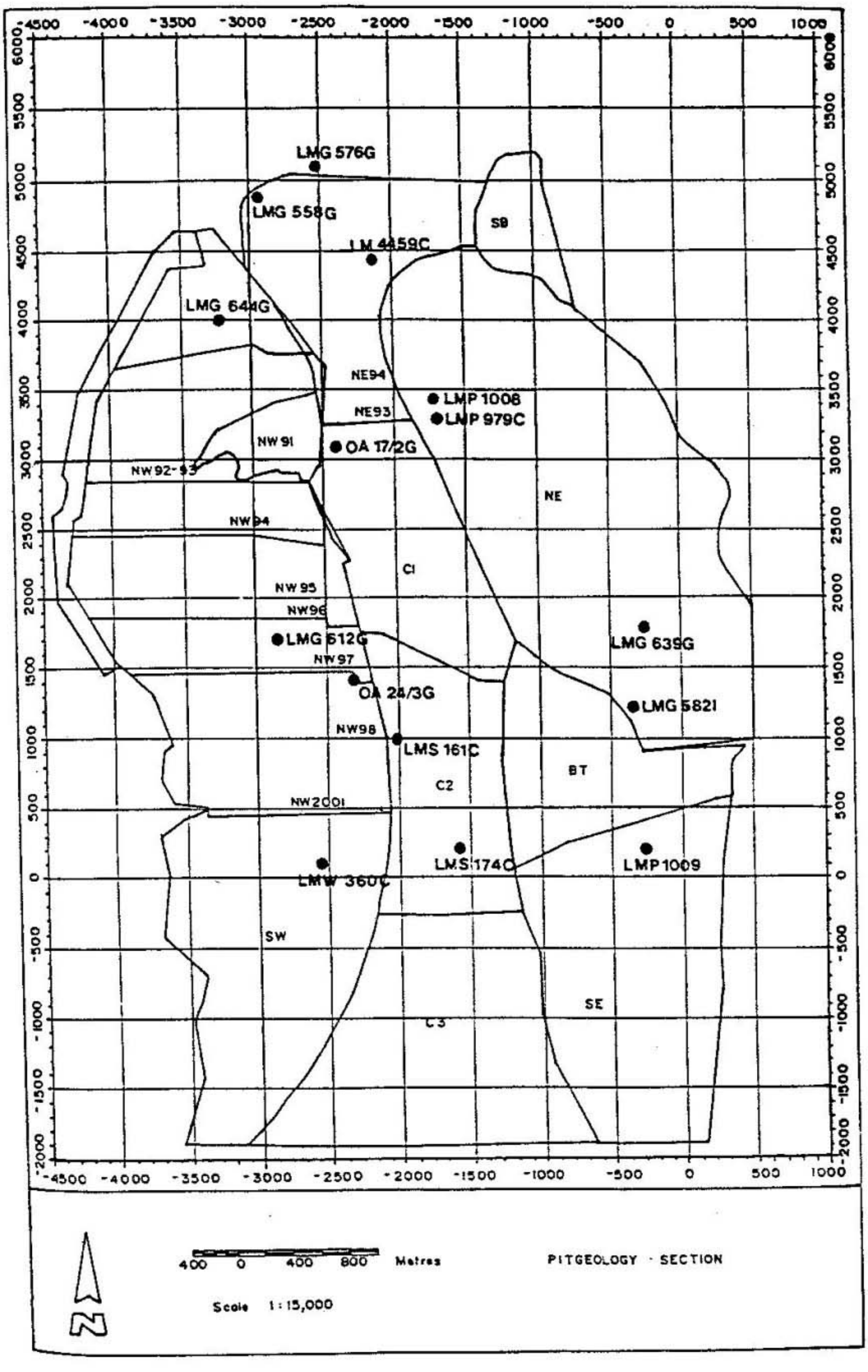

Figure 2 Location of core holes for sample collection

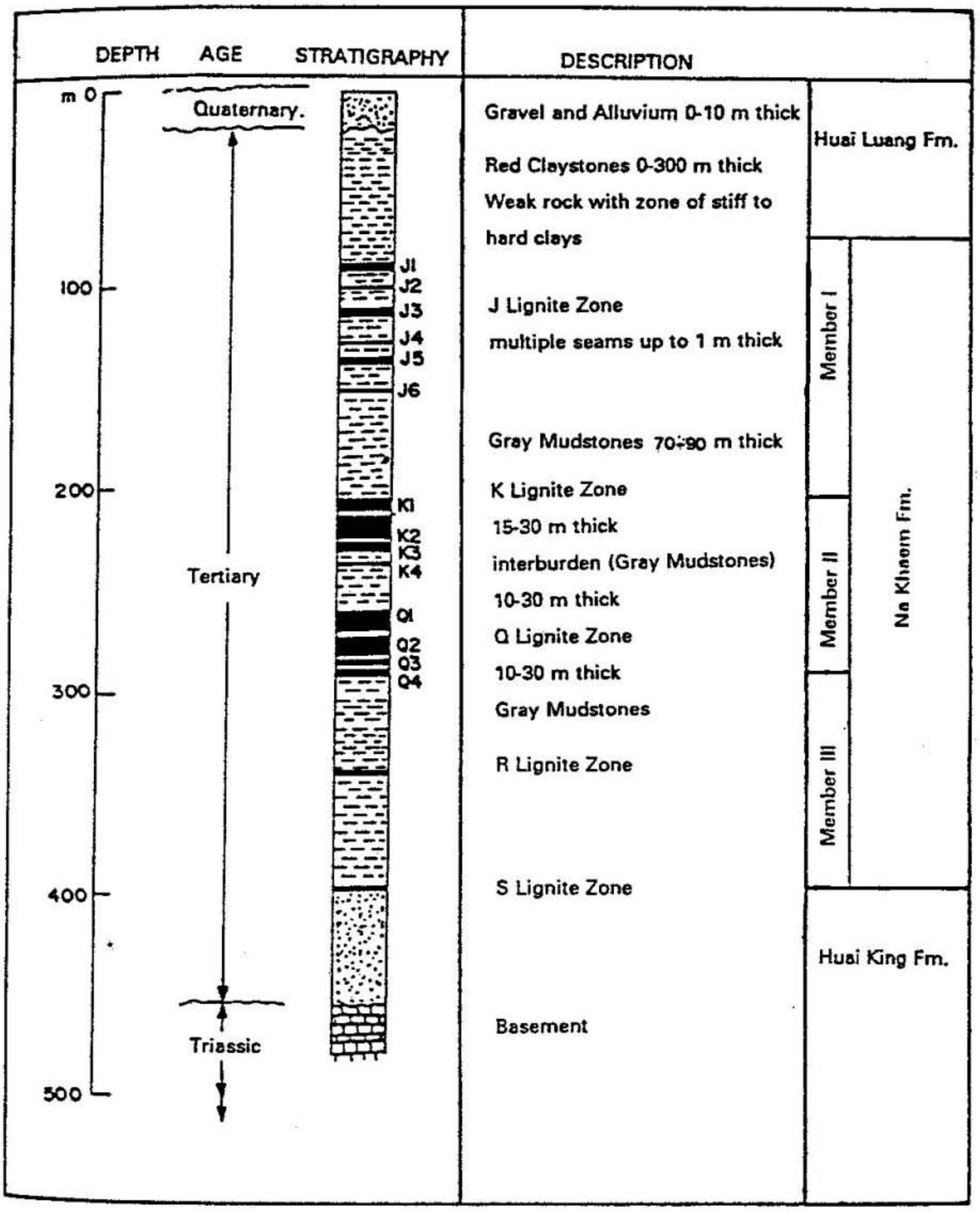

Figure 3 Stratigraphic column of the Mae Moh Basin showing distribution of the major coal seams and fine-grained clastic deposits

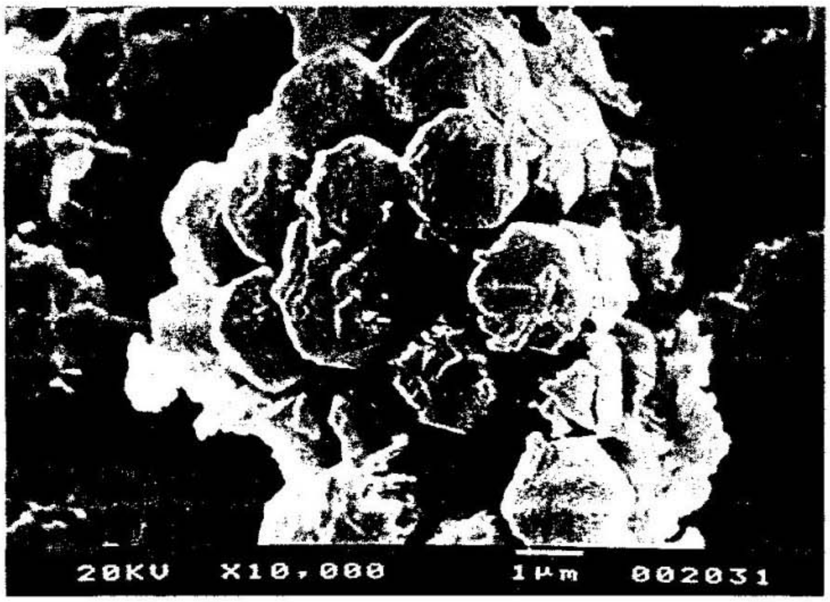

Figure 4A SEM micrograph of diagenetic kaolinite aggregate showing well-defined, hexagonal shape in mud rocks of Mae Moh interburden

Figure 4B SEM micrograph of Mae Moh interburden mud rock showing "stack" or sheet-like structure of kaolinite. (Sample no. LM 4459C, IB. PT. Q2-Q3 192.5-193 m)

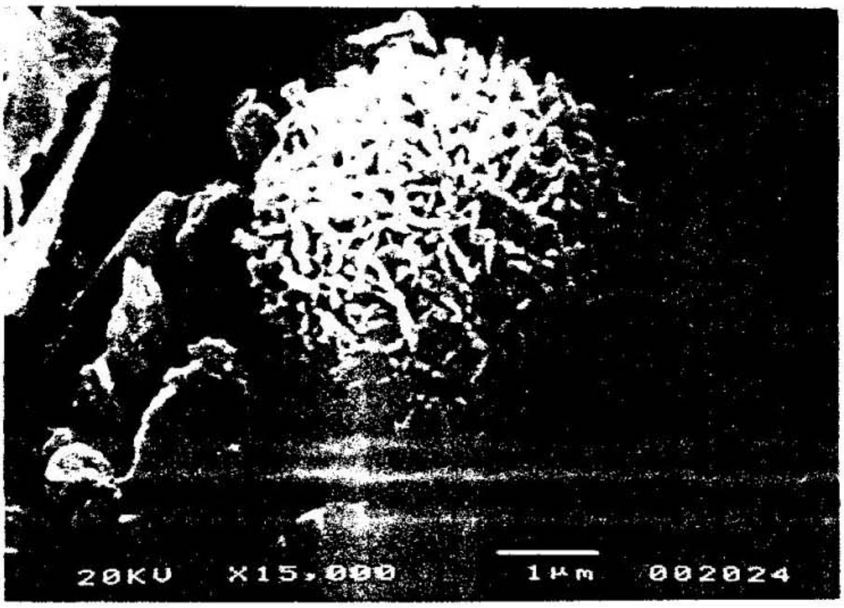

Figure 4C SEM micrograph of Mae Moh interburden mud rock showing gypsum crystals with well-defined tabular shape and prominent cleavages, in association with some calcite and clay minerals (Sample no. LMG 639G, IB. 14.5-15m)

Figure 4D SEM micrograph of Mae Moh interburden mud rock showing round-shaped bodies believed to be spores (Sample no. LMG 639G, IB. 14.5-15 m) kaolinite, sepiolite, smectite, illite with some mix-layered clays (corrensite), and chlorite. Illite and smectite may have formed as neo-mineral components. The greenish color in some mud rock layers and the appearance of abundant chlorite micaceous minerals suggest a volcanic source region. The occurrence of corrensite, sepiolite, and finely laminated mud rocks strongly support a fresh water to brackish water lacustrine environment. Fossil assemblages also indicate similar environments.

Geochemical analyses (Tables 1 and 2) of major oxides, using nondestructive X-ray diffraction methods, indicate that both the interburden and overburden Mae Moh mud rocks have significant fluctuations of some major oxides with depth. These rocks have large contents of SiO_2, CaO, Al_2O_3, FeO(T), K_2O, and LOI, but small contents of MgO, Na_2O, TiO_2, and MnO (Chaikiturajai, 1995; Kaewkask, 1995). Various plots of both major and trace elements (Figures 5 to 8) are indicative of the provenance and tectonic environment of the Mae Moh Basin. Treatments of these geochemical data (Figure 9) strongly imply that the Mae Moh mud rocks do not fall within the major types of tectonic settings, i.e., passive continental margins, active continental margins, continen-tal island arc, and oceanic island arc. However, a spider diagram plot (Figure 10) points to an intermediate igneous and mafic igneous provenance, implying the Permo-Triassic volcanic source region.

The above results, along with other data; (Table 3), suggest that the depositional environment of the Mae Moh Basin may have been lacustrine and that sedimentation took place in a fault-bound extensional and subsiding basin (Figure 11) and may have occurred in a rift tectonic setting during the Eocene Epoch.

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Table 1 Ranges and averages of some selected major oxide elements* of upper and lower overburden units of the Mae Moh mine.

Upper Unit	Range (%)	Average (%)	Lower Unit	Range (%)	Average (%)
SiO_2	8.23-45.44	27.68	SiO_2	21.11-49.94	38.7
Al_2O_3	3.81-16.02	11.00	Al_2O_3	7.58-15.73	13.73
CaO	7.91-41.07	23.24	CaO	5.9 -29.94	14.32
Fe_2O_3	1.97-8.34	4.89	Fe_2O_3	4.79-7.19	5.73
TiO_2	0.11-0.52	0.31	TiO_2	0.20-0.44	0.39
Na_2O	< 0.1	< 0.1	Na_2O	< 0.1	< 0.1
MgO	0.71-3.67	1.98	MgO	0.76-2.84	1.68
K_2O	0.44-2.35	1.54	K_2O	1.02-2.22	1.92
MnO	0.06-0.14	0.10	MnO	0.04-0.17	0.09
P_2O_5	0.07-0.17	0.12	P_2O_5	0.08-0.12	0.10
LOI	16.23-40.02	26.51	LOI	16.19-20.32	18.25

*Analyzed by the XRD method at the Mineral Resources Analysis Division, Department of Mineral Resources, Bangkok

Table 2 Ranges and averages of some major oxide elements* of upper, middle, and lower interburden units of the Mae Moh mine

Interburden / Oxide (%)	Upper Unit		Middle Unit		Lower Unit	
	Range	Average	Range	Average	Range	Average
SiO_2	11.7-47.8	31.1	31.1-63.2	51.5	35.1-42.9	39.1
Al_2O_3	5.0-19.4	12.4	12.4-13.1	13.1	14.8-18.2	16.5
Fe_2O_3	3.0-10.	6.6	3.4-5.5	4.3	4.3-5.7	4.9
CaO	11.2-36.5	17.8	5.8-20.9	10.9	9.8-17.4	13.6
K_2O	0.9-2.6	1.7	1.6-1.8	1.8	2.1-2.4	2.3
TiO_2	0.2-0.5	0.3	0.3-0.7	0.5	0.4-0.5	0.4
LOI	19.2-40.5	26.5	11.1-24.8	15.9	17.8-23.2	20.5

* Analyzed by the XRD methodat the Mineral Resources Analysis Division, Department of Mineral Resources, Bangkok

Table 3 Depositional environment and some evidences for the Mae Moh mud rocks

DEPOSITIONAL ENVIRONMENT	
Field Investigation and Petrography	
No sand, fine lamination or rhythmic lamination	= Lacustrine
XRD & SEM	
Illite and chlorite	= Detritial
Kaolinite, smectite	= Neomineral, diagenesis in low temperature lake
Corrensite and sepiolite	= Lake or lacustrine
Chemical Data	= Lake or lacustrine
Provenance	= Mafic, intermediate, felsic + limestone
PROPOSED TECTONIC SETTING	
Does not fit several proposed geological models Fault-bounded, rift-generating tectonic basin	

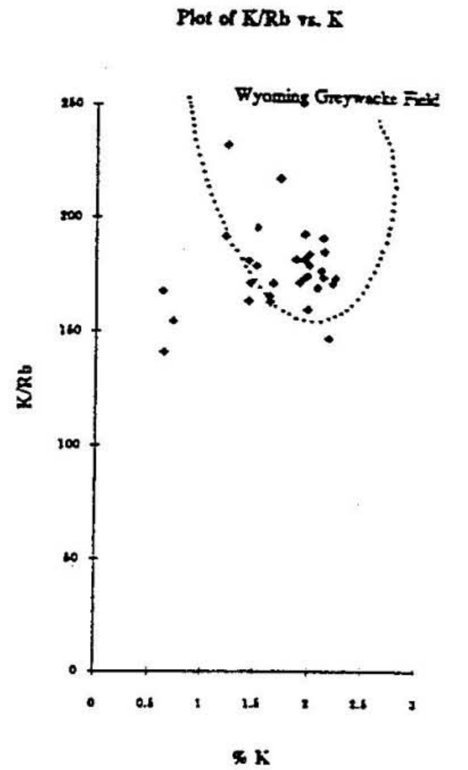

Figure 5A Plot of K/Rb vs. K showing distribution of Mae Moh mud rocks and Wyoming Greywacke Field, (after Condie, 1967)

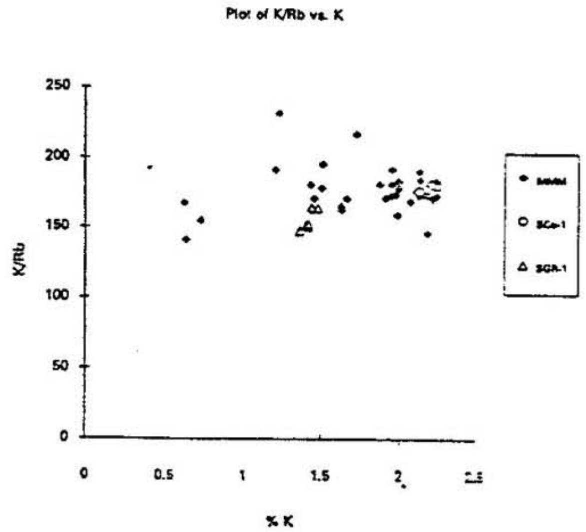

Figure 5B Plot of K/Rb vs. K showing distribution of Mae Moh mud rocks and Green River Formation, (MMM : Mae Moh mud rock) (Sco-1 : Cody Shale) (SGR-1 : Green River Formation)

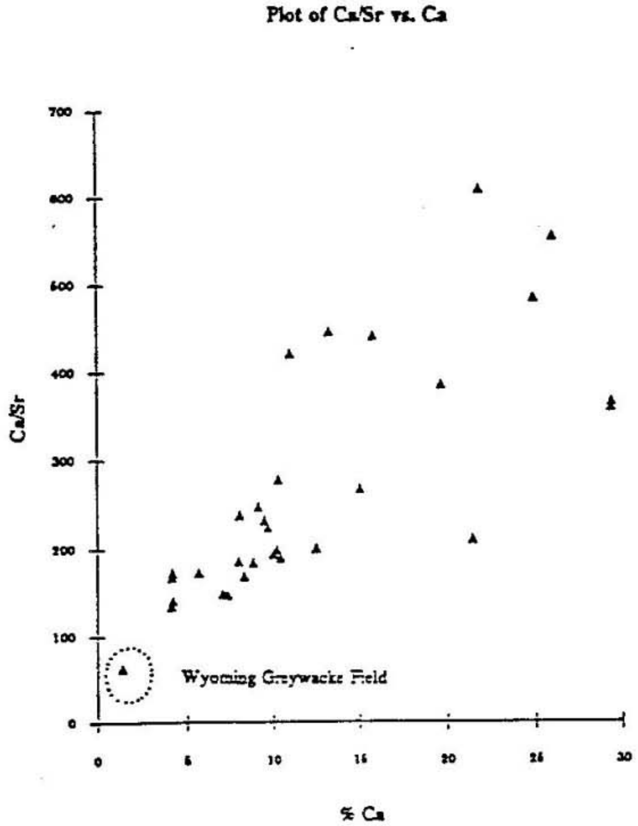

Figure 6A Plot of Ca/Sr vs. Ca showing distribution of Mae Moh mud rocks and Wyoming Greywacke Field (after Condie, 1967)

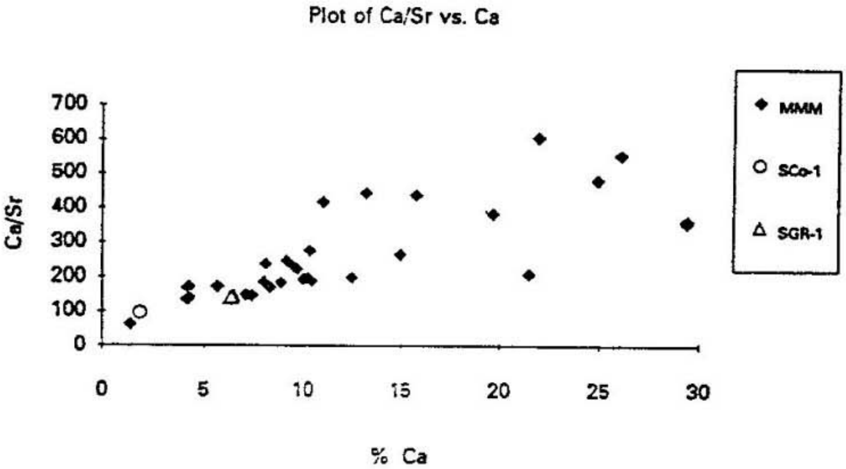

Figure 6B Plot of Ca/Sr Ca showing Mae Moh mud rocks and Green River Formation (MMM : Mae Moh mud rock)(Sco-1 : Cody Shale)(SGR-1 : Green River Formation)

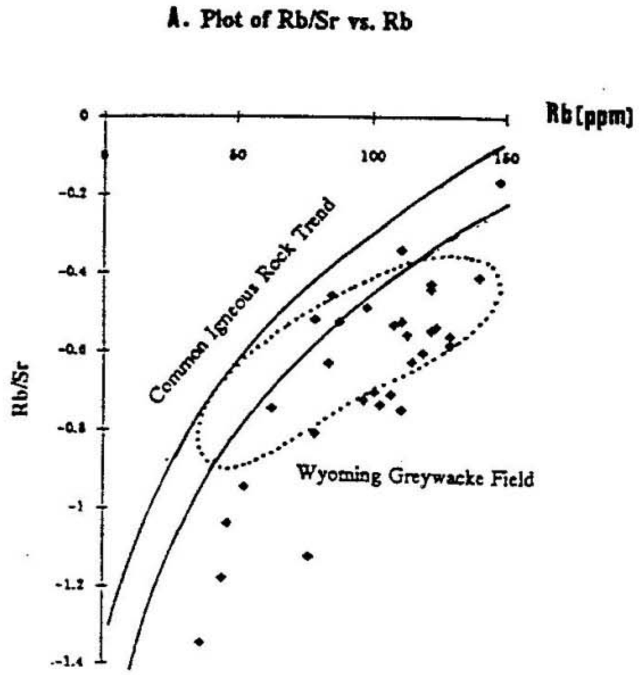

Figure 7A Plot of Rb/Sr vs. Rb showing distribution of Mae Moh mud rocks, Wyoming Greywacke Field and Common Igneous Rock Trend (after condie, 1967)

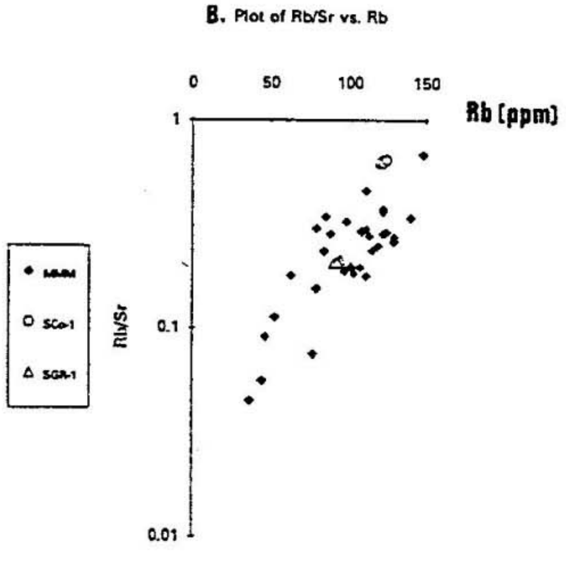

Figure 7B Plot of Rb/Sr vs. Rb showing distribution of Mae Moh mud rocks, and Green River Formation (MMM : Mae Moh mud rock) (Sco-1 : Cody Shale) (SGR-1 : Green River Formation)

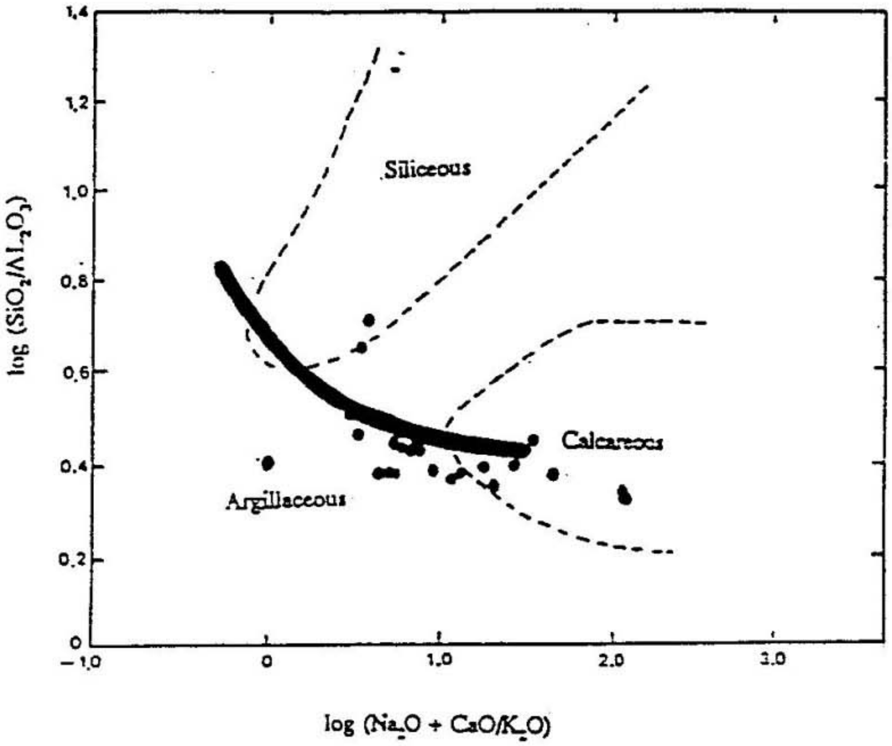

Figure 8A Plot of logarithms of the weight ratio of SiO_2/Al_2O_3 vs. $(Na_2O + CaO)/K_2O$ showing distribution of Mae Moh mud rocks and argillaceous, calcoreous, and igneous rocks shaded area (after Garrels and Mackenzie 1971)

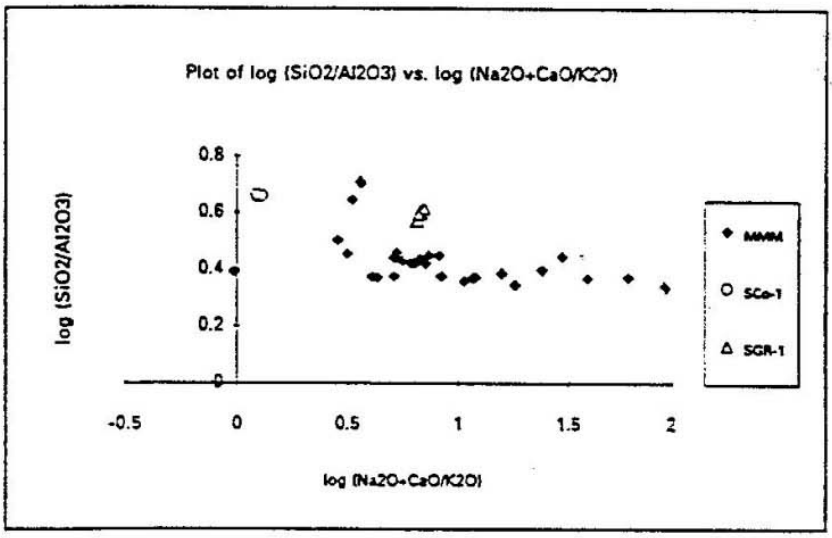

Figure 8B Plot of log SiO_2/Al_2O_3 vs. $(Na_2O + CaO)/K_2O$ showing distribution of Mae Moh mud rocks and Green River Formation (MMM : Mae Moh mud rock) (Sco-1 : Cody Shale) and (SGR-1 : Green River Formation)

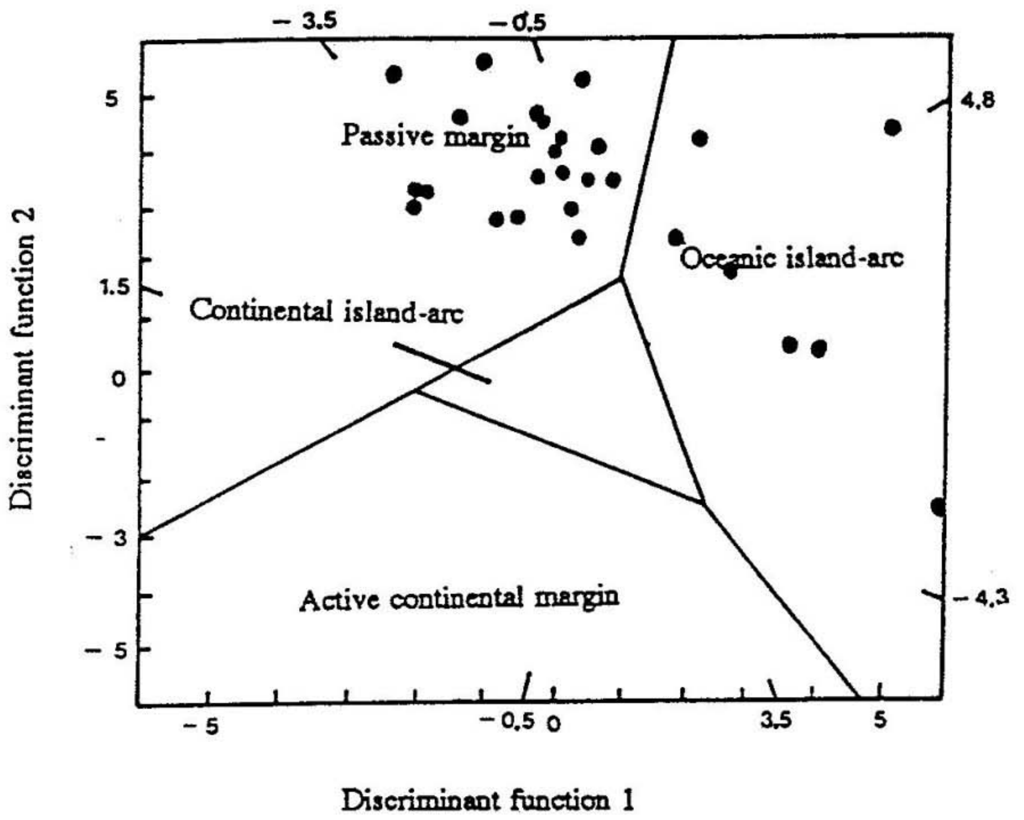

Figure 9A The discrimination diagram for Mae Moh mud rocks, with fields of four different tectonic settings (diagram from Bhatia, 1983). The discriminant fundtions are :

Discriminant function 1 = -0.0447SiO_2 - 0.972TiO_2 + 0.008 Al_2O_3 -0.267Fe_2O_3 + 0.208FeO - 3.082MnO + 0.140MgO 0.195CaO + 0.719Na_2O -0.032K_2O + 7.510P_2O_5 + 0.303

Discriminant function 2 = 0.421SiO_2 - 1.988TiO_2 - 0.526Al_2O_3 -0.551Fe_2O_3 + 2.720MnO + 0.881MgO - 0.907CaO - 0.117Na_2O - 1.840K_2O + 7.244P_2O_5 + 43.57

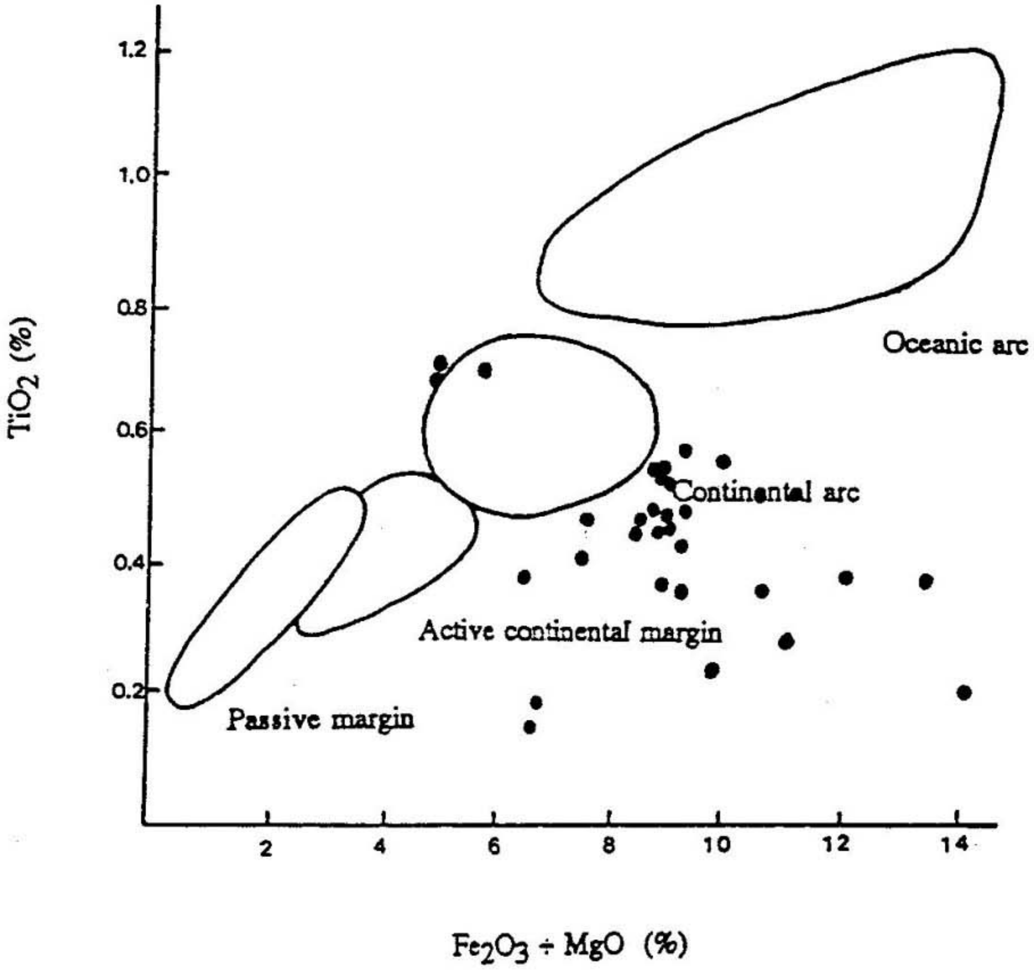

Figure 9B Discrimination diagram for Mae Moh mud rocks based on a bivariate plot of TiO_2 vs. Fe_2O_3(tot)+MgO (fields of tectonic settings from Bhatia, 1983)

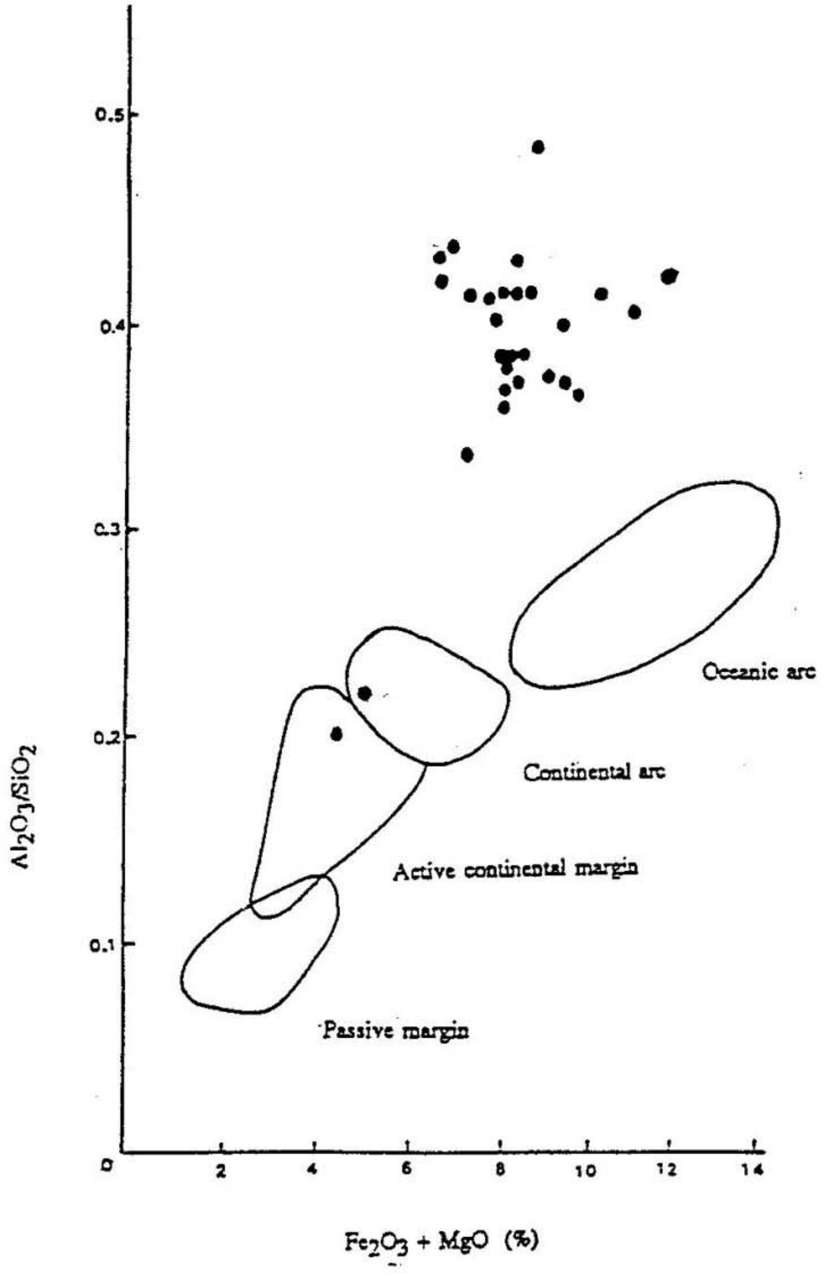

Figure 9C The discrimination diagram for Mae Moh mud rocks based on a bivariate plot of Al_2O_3/SiO_2 vs. Fe_2O_3 (tot)+MgO (fields of tectonic settings from Bhatia, 1983)

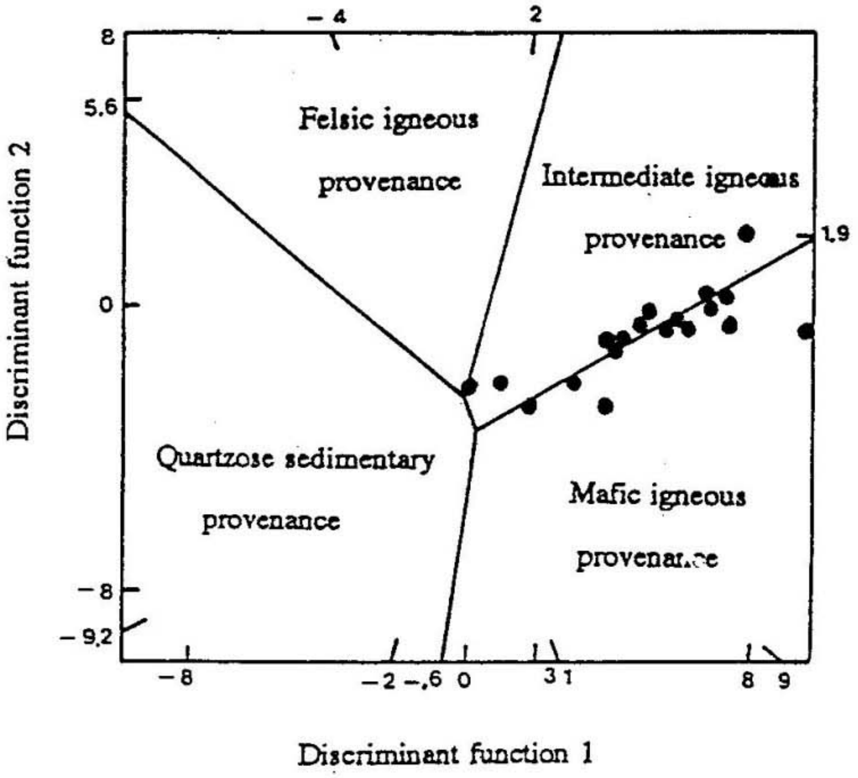

Figure 10 Discriminant function diagram for provenance signatures of sandstone-mudstone suites using major elements (after Roser and Korsch, 1988). Mae Moh mud rocks fit in a mafic to intermediate igneous provenance. The discriminant functions are :

Discriminant function 1 = -1.773 TiO_2 + 0.607 + 0.76 $fe_2O_{3\,(tot)}$ - 1.5 MgO + 0.616 CaO + 0.509 Na_2O - 1.224 K_2O - 9.09

Discriminant function 2 = 0.445 TiO_2 + 0.07 Al_2O_3 - 0.25 $Fe_2O_{3(tot)}$ - 1.142 MgO + 0.438 CaO + 1.475 Na_2O + 1.426 K_2O - 6.861

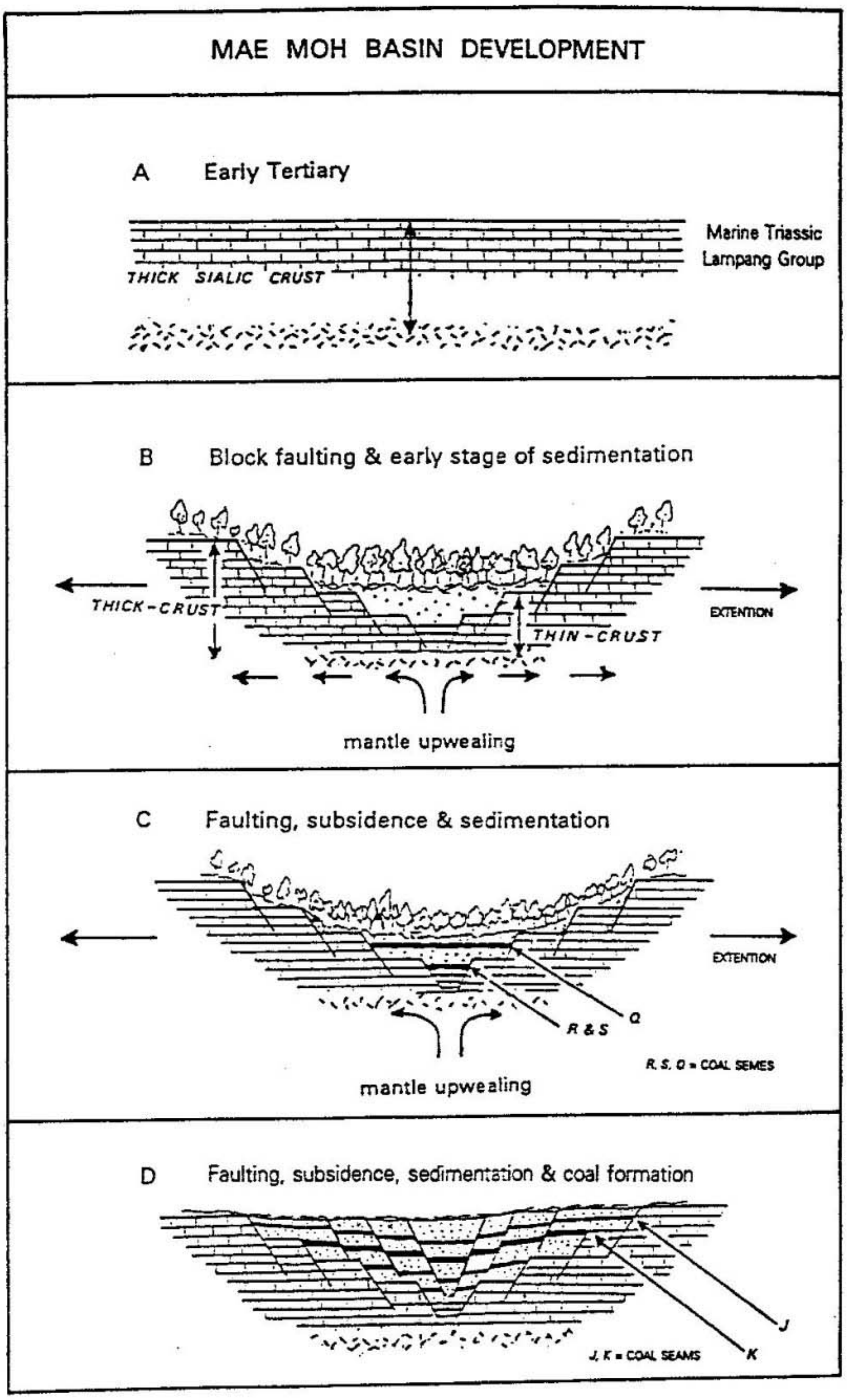

Fig. 11 Schematic model of Mae Moh basin development.