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Salinization in Northeast Thailand

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Abstract

Northeast Thailand covers an area of 170,230 km^2. This vast area should be agriculturally valuable, but actually its agricultural production per unit area is lower than those of other regions of the country. Low soil fertility, poor soil materials, uncertainty of climate and natural disasters are the main factors reported to reduce agricultural productivity.

One prevalent natural disaster in this region is salinity. Saline land is usually barren, for crops cannot tolerate the high salt content of the sub-soil or, sometimes, the surface soil. Certain weeds are tolerant to salinity and are used as salt-indicators: these include *nam phee*, *nam dang*, *yeak*, *phla*, and *mor*. Every year the acreage of saline soils is increasing and causing major problems for farmers in managing the land.

During April and May 1984, saline areas in the central and northern part of Northeast Thailand were investigated. These were classified into three major types on the basis of their topographic and geologic settings: hill, valley, and basin.

A major source of salt wherever it is exposed or lies close to the surface is the Rock Salt Member of the Maha Sarakham Formation, which consists mainly of rock salts. There are, however, other potential salt-sources that were formerly classified as salt-free strata. These are the Upper Clastic Member of the Maha Sarakham Formation and the Plio-Pleistocene Formation, which have recently been reported to contain traces of salts such as gypsum, sulfate, and carbonate, which replace halite.

The mechanism of salinization in this region is short-distance interflow of brine in source layers together with capillary rise. Interflow is of short distance because many of the scattered hillocks of the region are underlain by the Maha Sarakham Formation, while the Plio-Pleistocene Formation is also found in small sub-basins. Furthermore, broad, flat, low-lying topographies like the Phimai Plain and the Thung Kula Ronghai are still wrongly classified as alluvial plains, whereas in fact they are Plio-Pleistocene surfaces with alluvial patches and scattered patches of Maha Sarakham Formation. Salt that is weathered and eroded from salt-sources is transported either by surface water or by groundwater to low-lying lands. Whenever the ground surface is dry enough, salt precipitates from saturated brined surface water or rises from saturated brined groundwater.

I General Stratigraphy

Geologically, Northeast Thailand is usually called the Khorat Plateau because of its plateau-like topography. Fig. 1 is a location map of the Khorat Plateau, which contains two large basins, the Khorat – Ubol basin and the Sakon Nakhon – Udon basin. Fig. 2 is a simplified geologic map of the plateau. It is largely formed of clastic sediments of the Khorat Group, which have been dated to

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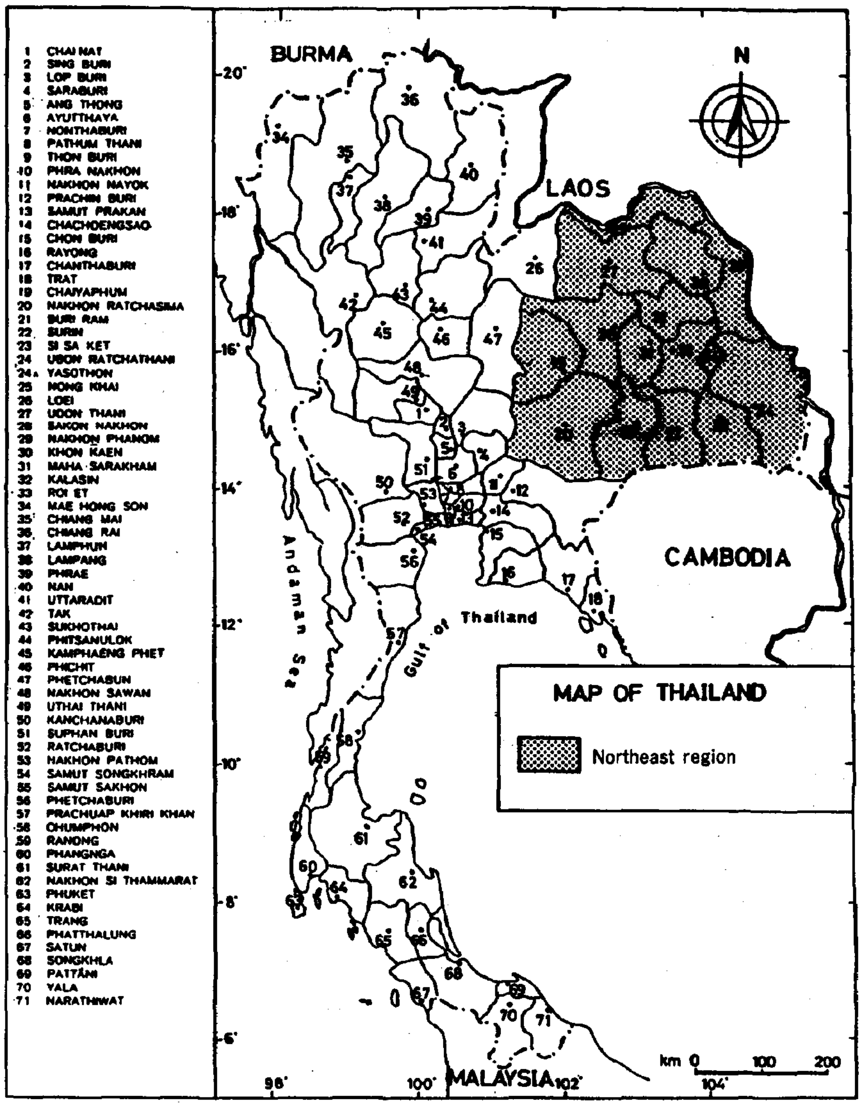

Fig. 1 A Location Map of the Khorat Plateau (Modified after Wongsomsak [1985])

Clastic; Takaya *et al.* [1985] divided it into two members: Rock Salt and Upper Clastic. The upper portion of Yumuang's Upper Clastic Member is classified as "Plio - Pleistocene Formation" by Takaya *et al.* [*ibid.*].

A more detailed subdivision of the youngest unconsolidated sediments had been presented by Wongsomsak [1985], as shown in Fig. 4. The Kham Sakae Saeng Formation is equivalent to the Plio-Pleistocene Formation, while the Khu Muang Formation and the Recent Washout Formation are respectively Pleistocene and Holocene formations.

the Mesozoic Era. The older formations of this group are salt-free, while the youngest one, the Maha Sarakham Formation or "Rock Salt Formation", is rich in salt and is a potential source of surface salt.

Fig. 3 is a simplified stratigraphic column of the Maha Sarakham Formation after Yumuang [1983] and Takaya *et al.* [1985]. Yumuang [1983] divided the Maha Sarakham Formation into six members: Basal Salt, Lower Clastic, Middle Salt, Middle Clastic, Upper Salt, and Upper

II Potential Sources of Surface Salt

1. *Rock Salt Member*

According to Yumuang [1983], of the Basal Salt Member is composed predominantly of clear halite, with subordinate amounts of carnalite, sylvite and anhydrite. The Middle Salt Member is also predominantly halite. There is, therefore, no doubt that the Rock Salt Member is a major source of salt.

As well as rock salt strata, however, the Rock Salt Member also contains salt-free

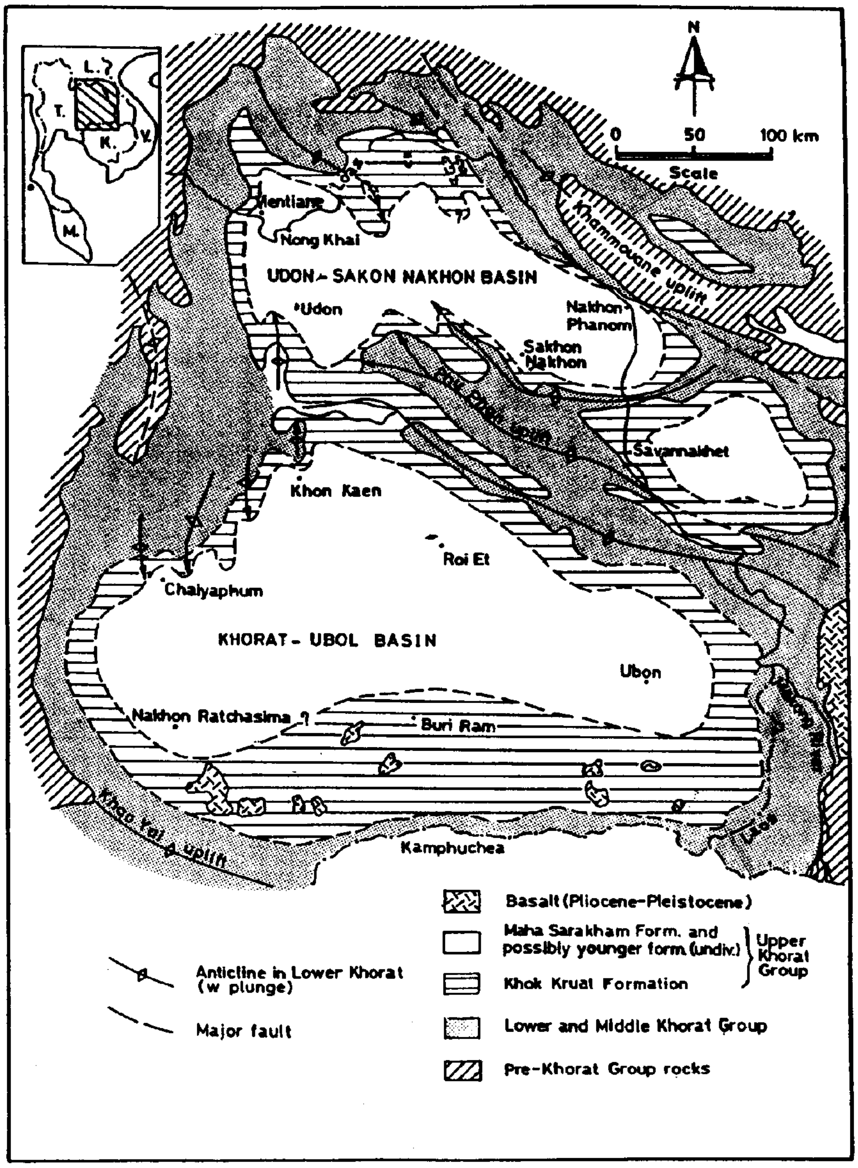

Fig. 2 Generalized Geological Map of the Northeast Thailand (Modified after Yumuang [1983])

strata. These rock strata, moreover, dip roughly toward the center of the Khorat Plateau at a gentle angle of 10–20 degrees. For these reasons the Rock Salt Member is not exposed throughout the region, and where it is exposed it is not necessarily salt-bearing. This is confirmed by the examples shown in Table 1.

2. *Upper Clastic Member*

This member lies on the Rock Salt Member and is regarded as a salt-free stratum. According to Yumuang [*ibid.*], the general lithology of the Upper Clastic Member is reddish brown and greenish grey semi-consolidated clay to claystone interbedded with calcareous claystone/mudstone and siltstone/sandstone, and bearing gypsum veins and veinlets and scattered gypsum/anhydrite layers.

Takaya *et al.* [1985] have reported indications of salt in the Upper Clastic Member, which, therefore, must now be regarded as a salt-bearing rather than salt-free stratum. The following are examples of the salt indications.

(a) Red siltstone located about 42 km from Nakhon Ratchasima on the road to Khon Kaen reacts to silver nitrate.

(b) Red siltstone at Ban Toei about 30 km NNW of Phimai shows an EC of 4,100 Ms/cm.

(c) Red siltstone at Ban Nong Muang about 9 km NE of Phimai is salty.

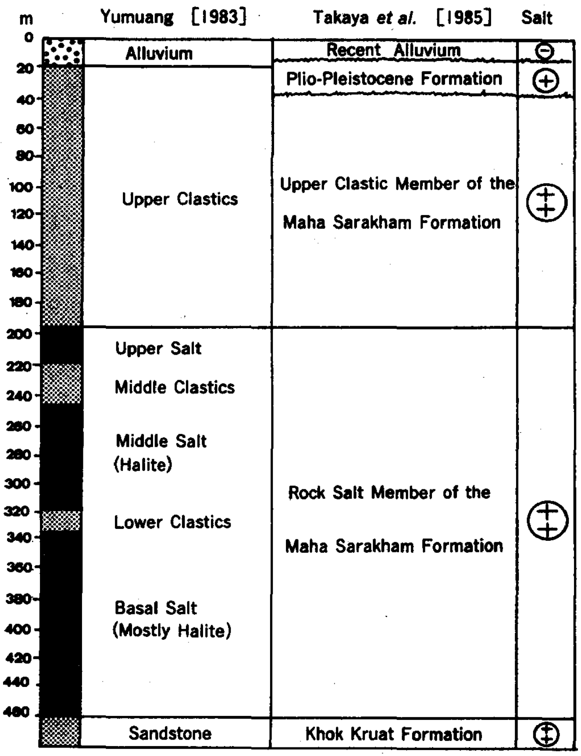

Fig. 3 A Simplified Stratigraphic Column Shows Previous Subdivisions of the Maha Sarakham Formation (Modified after Takaya *et al.* [1985])

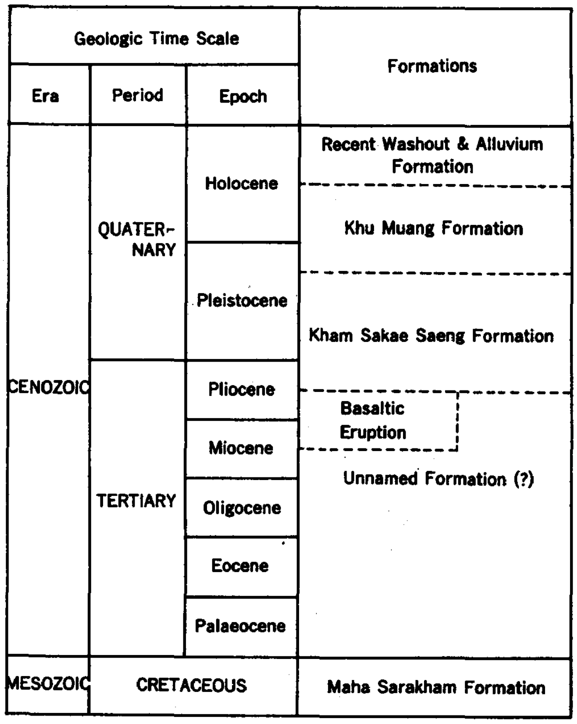

Fig. 4 A Representative Cenozoic Stratigraphy in Northeast Thailand (Modified after Wongsomsak [1985])

3. *Plio-Pleistocene Formation*

This formation was not formerly recognized, being confused with alluvium because its materials are much less consolidated than that of the Maha Sarakham Formation. It is not surprising, therefore, that it is often classified as alluvium. This would be appropriate had a tektite horizon not been found overlying the Plio-Pleistocene stratum in the vicinity

Table 1 Some Exposures and Analytical Data of the Rock Salt Member of the Maha Sarakham Formation (Modified after Takaya *et al.* [1985])

Depth (m)	Location	Lithology	pH	EC (μ℧/cm)	Total Extractable Bases (meq/100 g soil)	Na/Total Base (%)	Cl⁻ Content	Carbonate
2.8	Rice field along the Non Thai – Kham Sakae Saeng road	Red siltstone	7.4	6,000	69.71	28.9	卌	±
—	Natural outcrop in Nong Muang along the Borabu – Ban Dong Wan road	Red siltstone	7.8	760	28.52	37.1	++	—
—	Dug pond at Ban Khok Krasang, Amphoe Non Thai, Nakhon Ratchasima	Red siltstone	9.5	240	59.89	6.5	—	卌

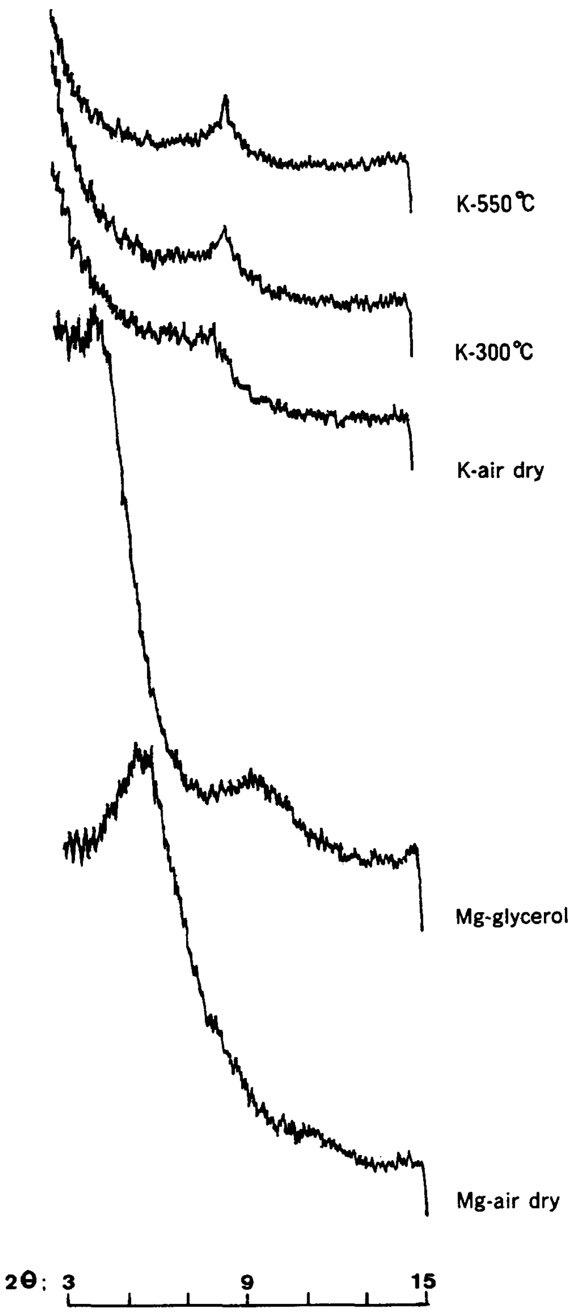

Fig. 5 A Typical X-ray Diffractogram of the Kham Sakae Saeng Formation (Equivalent to the Plio-Pleistocene Formation), at the Type Locality (Modified after Wongsomsak [1985])

of Amphoe Kham Sakae Saeng. The tektite has been dated as 600,000 years old. Wongsomsak [1985] called this the Kham Sakae Saeng Formation from the name of the locality.

The material of the Plio-Pleistocene Formation is entirely clay with a distinctive white to light matrix color and brownish yellow mottles, often containing large calcium carbonate nodules.

Clay mineralogical study shows that the light colored clay has a narrow range of clay mineral composition. Fig. 5 shows a typical X-ray diffractogram of this formation. Montmorillonite and kaolinite are the dominant constituents and are present in similar proportions. Further study, however, has revealed that montmorillonite is usually more dominant than kaolinite in many places. Mica is also present in small amount.

Table 2 gives a description and laboratory data of outcrops of the Plio-Pleistocene Formation.

Fig. 6 is a schematic drilling core profile of the so-called Upper Clastic Member [Takaya *et al.* 1985]. The portion to 10 m depth is unclassified because of poor sampling. At the depth of 10 to 16 m, the white to gray loamy part is equivalent to the yellow-mottled Plio-Pleistocene sediments often encountered in natural exposures or in auger holes. This portion neither shows traces of gypsum, nor is it salty. Nevertheless, the fact that its pH is higher than 8 confirms its salt content.

At depths below 16 m, gypsum crystals have been found in three horizons: a sand layer at the depth of 16 to 20 m, a laminated sand and clay layer at the depth of 30 to 38 m, and a disturbed siltstone layer just beneath the laminated layer. Sulfur-like yellow powder is also found in the last two layers. The sediments below 16 m deep

Table 2 Some Exposures and Analytical Data of the Plio-Pleistocene Formation (Modified after Takaya *et al.* [1985])

Depth (m)	Location	Lithology	pH	EC ($\mu℧$/cm)	Total Extractable Bases (meq/100 g soil)	Na/Total Base (%)	Cl^- Content	Carbonate
1.2	Slightly undulating rice field with termite mounds, 1 km west of Ban Khang Phlu Thai, on the Khok Kruat – Non Thai road	White (10YR 2/1) sandy clay, many yellowish brown (10YR 5/8) cloudy mottles, many calcium carbonate nodules (5–10 cm)	8.8	1,280	28.64	70.5	+++	++++
2.2	Very slightly undulating rice field, north of Khok Sung village along the Cho Ho – Non Thai road	Light olive gray (2.5GY 7/1) loamy clay, many brownish yellow (10YR 6/6) and yellowish brown (10YR 5/8) cloudy mottles	9.2	620	18.97	28.2	++	—
2.7	Same as the second location	Light greenish gray (7.5GY 7/1) clay, common brownish yellow (10YR 6/8) cloudy mottles, many manganese pisoliths	8.6	1,400	22.18	32.3	+++	—
1.5	Flat rice field with scattered sand patches at Ban Tamyae, west of Amphoe Phimai along the Phimai – Khorat road	Light gray (2.5Y 7/2) loamy clay, few faint yellow to brownish yellow (2.5Y 7/6 – 10YR 6/8) cloudy mottles, common manganese pisoliths	8.6	470	21.10	42.3	+++	—
0.6	Canal bank, 1 km east of Amphoe Phimai along the RID's main canal	Light gray (10YR 7/9) silty clay loam, many faint brownish yellow (10YR 6/8) cloudy mottles, many round iron concretions	7.2	4,200	32.31	53.3	++++	—

are to some extent salt-bearing, and the gravel horizon between 29 and 30 m has a strong salty taste.

Whether the salt in the Plio-Pleistocene Formation is syngenetic or postgenetic, this formation provides another potential source for surface-soil salinization, together with the Upper Clastic Member and the Rock Salt Member of the Maha Sarakham Formation. Field evidence confirms that carbonate-bearing facies of the Plio-Pleistocene Formation are often salt-bearing, while carbonate-free facies are usually salt-free.

III Areas of Salinity

The nature of salinity in the Khorat

Plateau, especially the Khorat - Ubol basin, can be more clearly understood by dividing the basin into three areas: hill, valley, and basin. These areas are shown in Fig. 7. Each area, moreover, possesses its own geologic setting, as shown in Fig. 8.

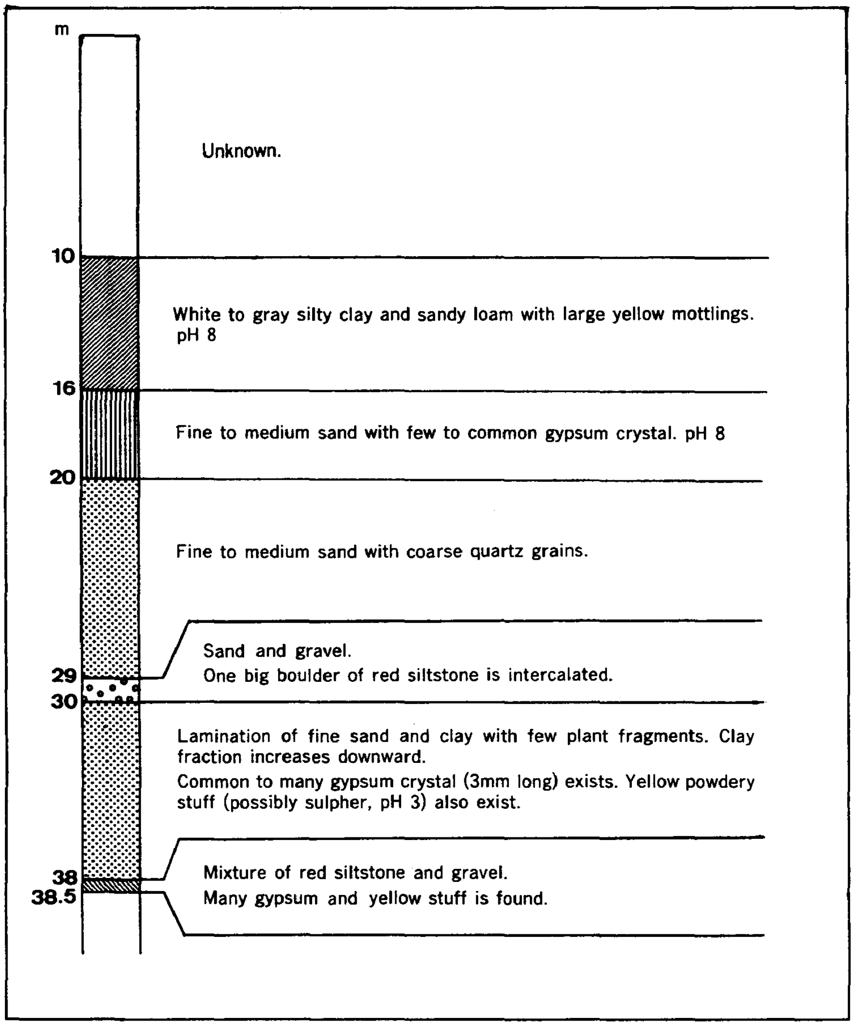

Fig. 6 A Schematic Drilling Core Profile of the Plio-Pleistocene Member at Bamnet Narong, Changwat Chaiyaphum (Modified after Takaya *et al.* [1985])

1. *The Hill Area*

Covered mostly by large and small hills, this area is located to the west of the Nakhon Ratchasima – Non Thai – Chaiyaphum road. Geologically, the area is underlain by the Rock Salt Member of the Maha Sarakham Formation. Salinization here takes two forms: directly on the salt-bearing rock, and on footslopes due to seepage.

1–1. Salt on Salt-bearing Rock

Salt appearing directly on salt-bearing rock can be subdivided into three types according to its characteristic features and lithology.

Salt Derived from the Rock Salt Member by Weathering: The elevation of this area has lead to exposure of basement rock of the Rock Salt Member through erosion. Existing outcrops are, however, difficult to identify as the Rock Salt Member because they have lost their original features almost completely due to weathering processes. They contain half-indurated gray sand and bluish gray clay with many manganese pisoliths or aggregates of carbonate nodules. They also contain many pores and minute channels, which are evidence that the original salt of the Rock Salt Member has been leached out. NaCl is absent in the outcrops, but at depths of several meters below the surface, some of the original halite should be retained in the fresh rock.

Salt in Caved-in Troughs: A schematic model of this feature has been proposed by

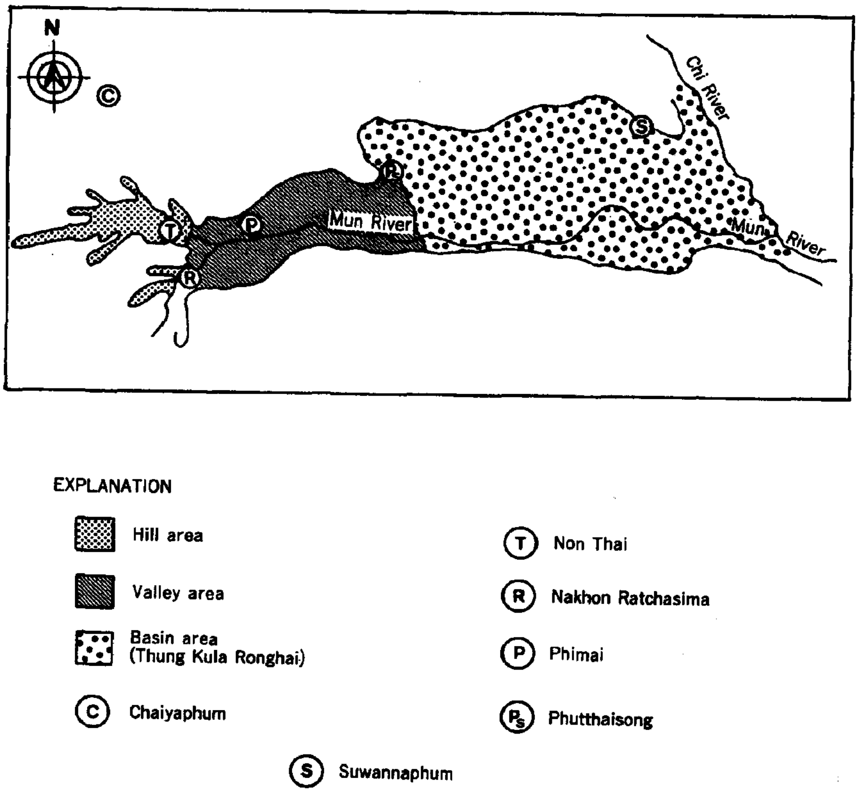

Fig. 7 Three Salinity Areas in the Mun River Drainage (Modified after Takaya *et al.* [1985])

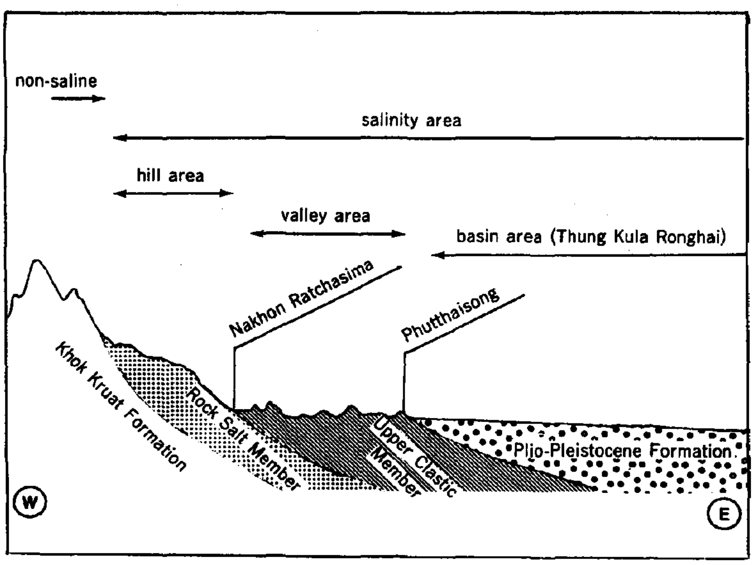

Fig. 8 Schematic E–W Profile Shows a Relation between Salinity Area and Geologic Setting along the Mun River (Modified after Takaya *et al.* [1985])

Takaya *et al.* [*ibid.*] as shown in Fig. 9. The combination of salt-rich and salt-free beds of the Rock Salt Member together with their gently dipping lie give rise to different degrees of weathering, resulting in uneven topography. The salt-free beds become ridges, the salt-rich beds troughs. An example of this feature is shown in Fig. 10, which is a 1 : 50,000 topographic map of the area around the Ban Sarakham Formation. Between ridges, the valley-like topography is occupied by paddy fields and swamps. Soil in this zone is dominated by clay and a small amount of sand. This confirms that the depressions are not fluvial valleys but a sort of caved-in trough. Were they of fluvial origin, they would be expected to be filled with sand from the surrounding sandy ridges. Often these valley-like depressions lack an outlet, appearing as elongated basins surrounded on all sides by high ground. Here, therefore, the Rock Salt Member is exposed

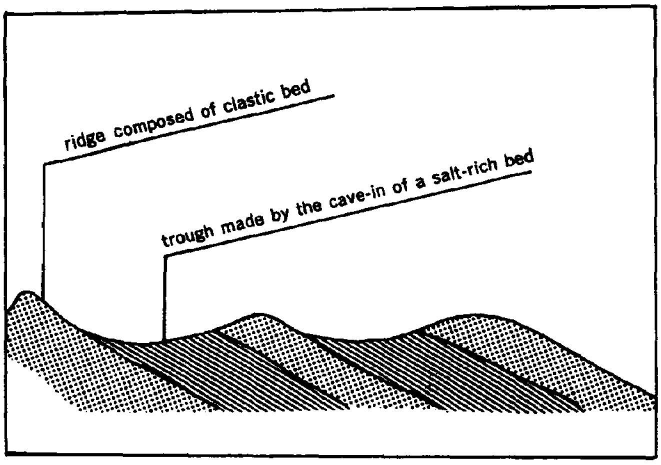

Fig. 9 Schematic Section to Show the Development of Ridge and Troughs in the Hill Area (Modified after Takaya *et al.* [1985])

directly at the ground surface and the area is highly potentially saline soil.

Salt in "Nam Dun": "*Nam dun*" is the name given by farmers in the Khon Kaen area to a peculiar topography with scattered small pimple mounds, where the Rock Salt Member is exposed at the surface. Active and non-active *nam dun* are distinguished according to their surface activity.

Active *nam dun*, or soft pimple mounds, have a soft, fluid surface that readily swells underfoot into mire. The *nam dun* reported at Tambon Don Daeng, about 15 km SE of Khon Kaen, are assumed to be soft, sandy loam lenses perching on the Maha Sarakham Formation. The bulk of the sandy clay loam is reported to consist of only two-thirds solid material and one-third water. Laboratory analysis of these pimple mounds is shown in Table 3. The clay mineralogy is dominated by montmorillonite (Fig. 11a), which is thought to be the agent that makes the *nam dun* soft, fluid and swelling.

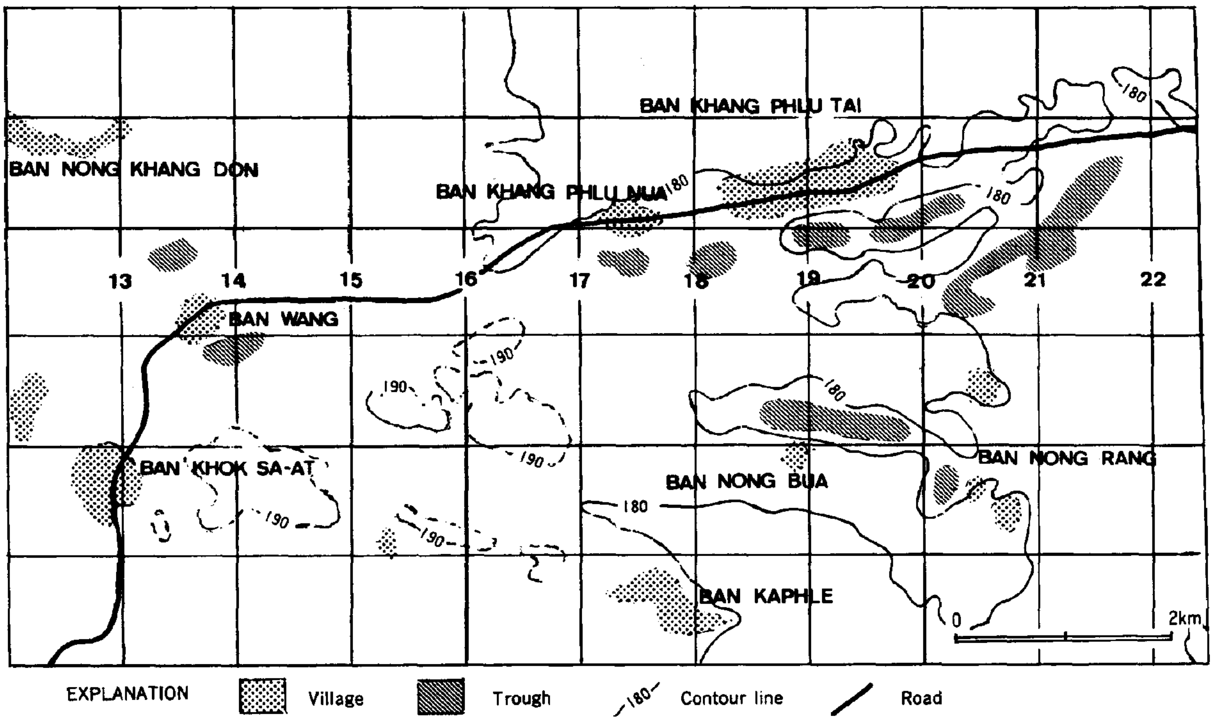

Fig. 10 An Example of the Ridge-trough Combination at Ban Khang Phlu Tai (Modified after Takaya *et al.* [1985])

Table 3 Description and Analytical Data of *Nam Dun* (Modified after Takaya *et al.* [1985])

3a

Location	Depth (m)	Lithology	pH	EC ($\mu\mho$/cm)	Total Extractable Bases (meq/100 g soil)	Na/Total Base (%)	Cl^- Content	Carbonate
Ban Khum Phaya, 13–15 km north of Amphoe Kham Thale Sa along the Kham Thale Sa – Non Thai road	0–0.5	Pink quartz	—	—	—	—	—	—
	0.5–0.6	Pink to light reddish brown (5YR 6/3) sandy clay loam to sandy loam with few dark brown (7.5YR 4/6) concretionary mottles	10.0	500	45.12	5.2	—	+++
	0.6–0.9	Pinkish white (5YR 8/2) silty clay with common calcium carbonate nodules and common manganese pisoliths	9.2	360	40.88	7.7	—	++++
	0.9–1.7	Pinkish white (5YR 8/2) silty clay with profuse large calcium carbonate nodules	9.9	310	52.55	3.7	±	++++

3b

Location	Mineral Composition			pH	EC ($\mu\mho$/cm)	Chemical Composition											
	Sand (%)	Silt (%)	Clay (%)			Si (%)	Al (%)	Fe (%)	Ti (%)	Na (%)	Mg (%)	K (%)	Ca (%)	S (ppm)	P (ppm)	Mn (ppm)	Cl (ppm)
Tambon Don Daeng, about 15 km south-east of Khon Kaen	65.5	24.8	9.7	7.1	2,290	36.8	6.08	0.92	0.20	1.30	0.47	1.29	1.60	70	70	80	1,890

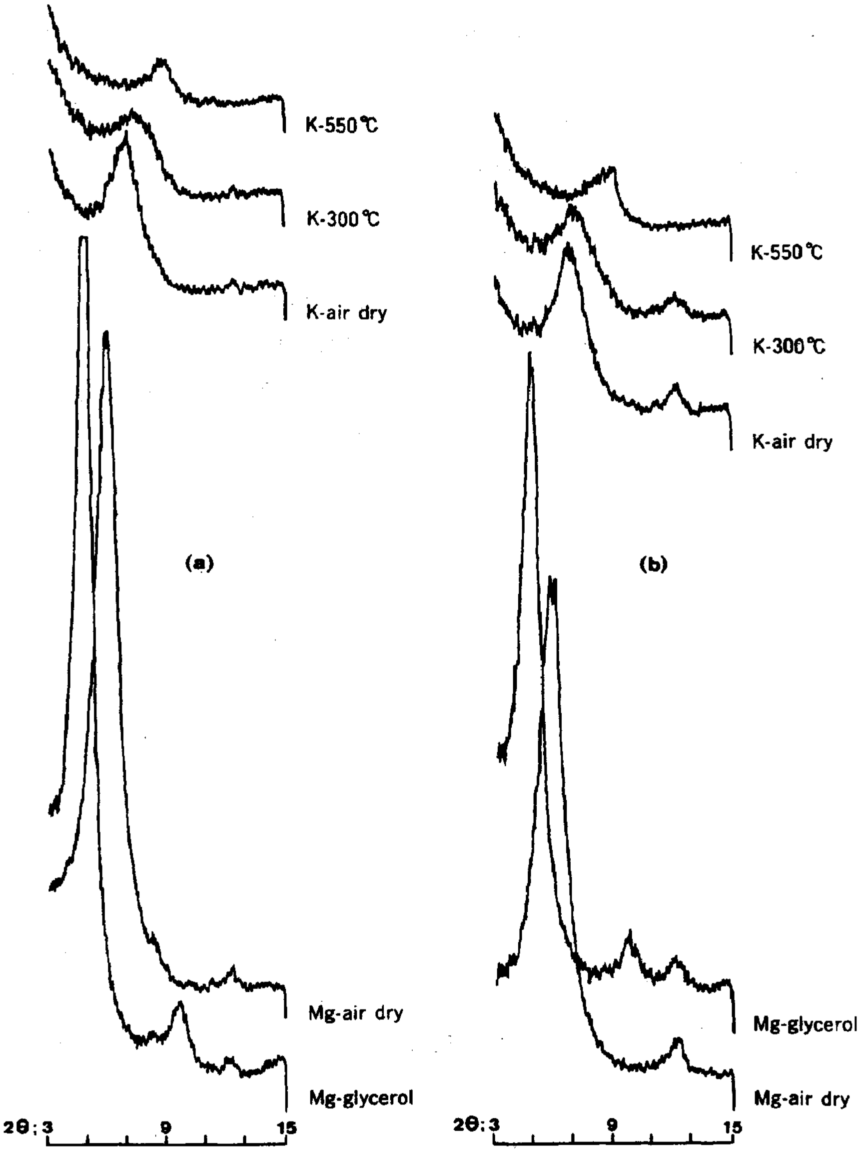

Fig. 11 X-ray Diffractograms of *Nam Dun* Clay Show the Dominance of Montmorillonite
(a) Ban Don Daeng, (b) Ban Khum Phaya

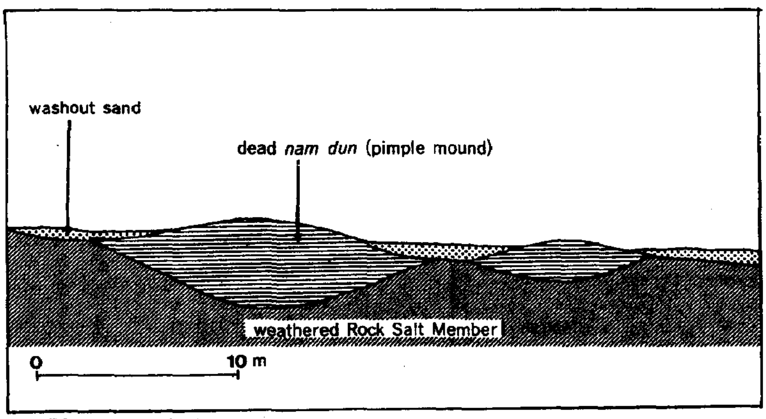

Fig. 12 A Schematic Cross Section of the Pimple Mound (Modified after Takaya *et al.* [1985])

Non-active *nam dun* are hard pimple mounds whose surface is a honey-comb-structured crust of calcium carbonate. One example is in the north of Ban Khum Phaya, Amphoe Kham Thale Sa, lying 13 to 15 km north of Amphoe Kham Thale Sa along the Kham Thale Sa – Non Thai road. The very hard honeycomb crust of calcium carbonate that covers quartz sandy material containing calcium carbonate is only 0.5 m thick. The lowest layer is more sandy and of a peculiar reddish purple color (5YR 4/4), and groundwater appears at a depth of 1 m. The bulk density of the hard crust is very low. The surroundings of this non-active *nam dun* are reported to have a calcium carbonate crust covered by washed-out sand. An idealized cross section through a pimple mound is illustrated in Fig. 12 (after Takaya *et al.* [*ibid.*]). The presence of montmorillonite (Fig. 11b) together with pores and channels in the sandy material is evidence that, during an active period, montmorillonite was washed away by voluminous groundwater.

1–2. Salt on Footslopes

Salt also frequently accumulates on footslopes, usually in association with isolated hillocks.

Fig. 13a is a schematic east–west cross section of salt accumulation on a footslope near Ban Khum Phaya (after Takaya *et al.* [*ibid.*]), and Fig. 13b shows the stratigraphy in three ground-level pits on the slope. These pits show similar profiles, especially at their deepest portions, which are thought to be salt-bearing beds of the Maha Sarakham Formation. These are dominated by montmorillonite in clay mineral composition, and have high to fairly high EC, high Cl, and considerable total extractable bases (Table 4). These facts are consistent with the common phenomenon of fresh water on top of a hillock becoming saline in the footslopes. The dipping angle and the alternation of clastic and salt-bearing beds of the Maha Sarakham Formation are also closely related to this type of salinity.

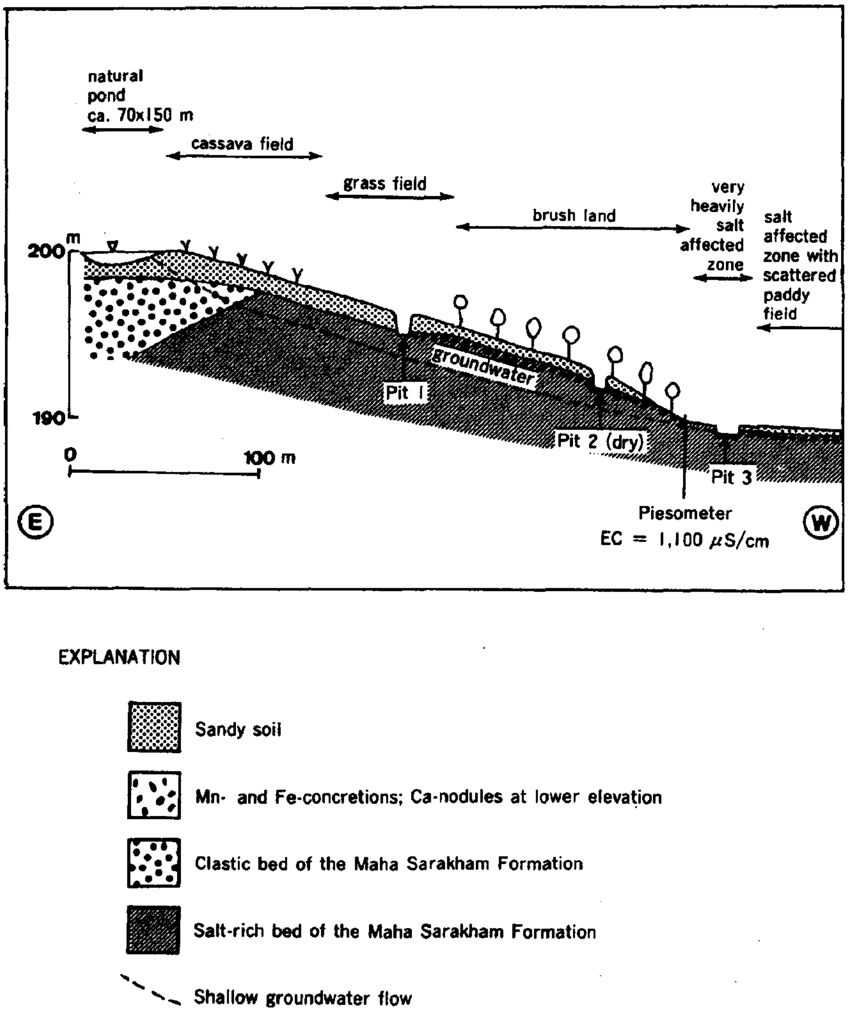

Fig. 13 a A Schematic E–W Cross Section through DLD's Piezometer No. 27, Ban Khum Phaya, to Show a Development of Salinization on Footslope (Modified after Takaya *et al.* [1985])

2. *The Valley Area*

The mechanism of salinization in the valley area is similar to that in the footslopes of the hill area. Brine originating from surrounding hills is carried into the valley either by subsurface or surface flow, and salt is precipitated on the valley floor.

Brine interflow under cap clay is a major process in salinization in the valley area. Fig. 14 is a schematic north–south cross section at Ban Khok Sung, along the Cho Ho – Non Thai road, which is located on a small hill of red siltstone of the Maha Sarakham Formation. Recent alluvium forms a sandy layer, below which is the Plio-Pleistocene

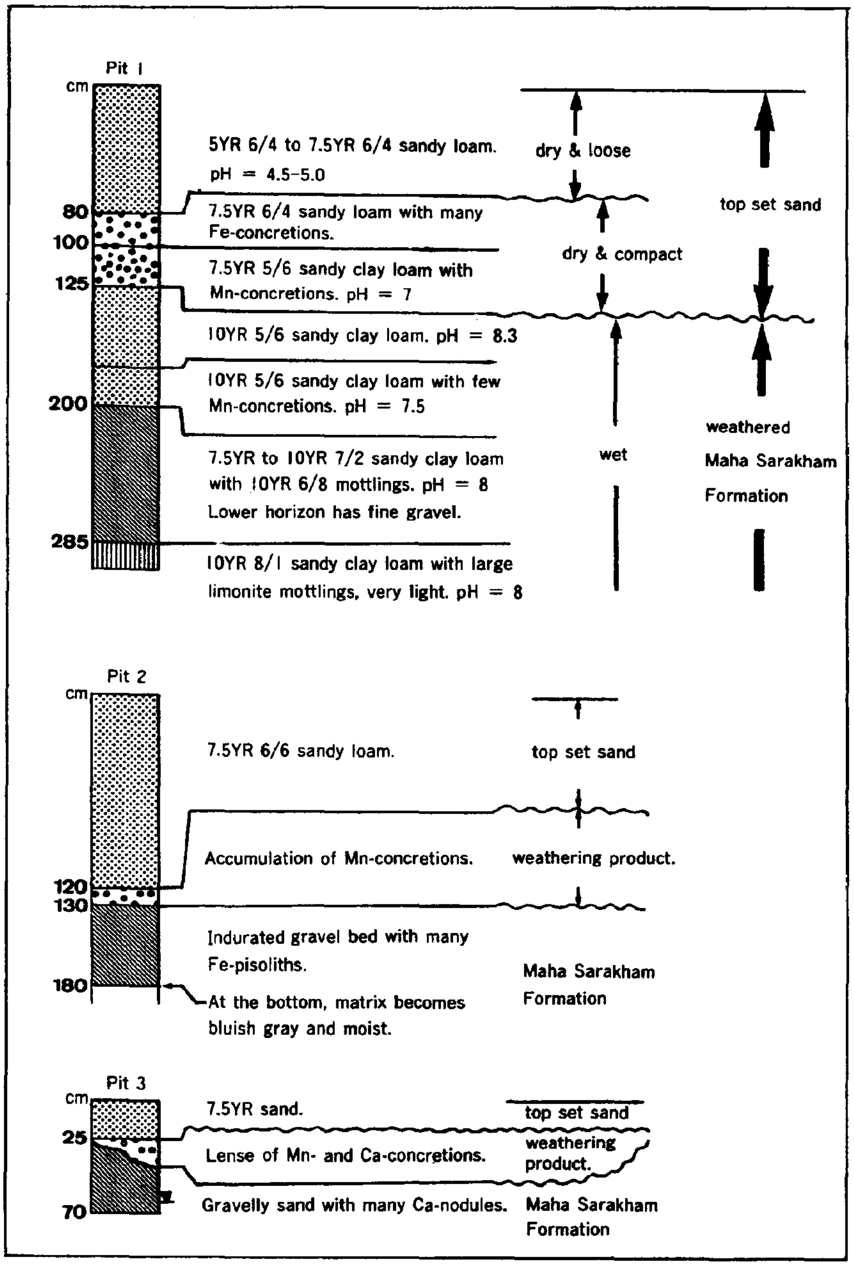

Fig. 13 b Profiles of the Three Pits Dug along the Cross Section Shown in Fig. 13 a (Modified after Takaya *et al.* [1985])

Formation, usually with loamy sand texture.

Two profiles through this valley have been examined in both the field and the laboratory (Table 5). The results show that profile A has a non-saline topsoil and more or less saline subsoils, while profile B has saline topsoil. This difference is due to a difference in the thickness of the Recent alluvium cap, which retards capillary rise of brine in the Plio-Pleistocene Formation. Profile A is covered by a thick cap of Recent alluvium, which retards capillary rise to the extent that the ground surface remains salt-free, although the EC gradient indicates that brine does rise from the Plio-Pleistocene clay-bed to overlying beds. On the other hand, profile B has only 20 cm of cap clay, and brine readily reaches the ground surface by capillary rise.

The area represented by profile B is called a saline area because it has saline spots. The area represented by profile A, on the other hand, is called a potential saline area, because salinity can appear immediately on the ground surface if the cap is removed or made thinner. Mosaics of potential saline patches and saline patches usually form on the lowland of the valley area.

A sub-type of saline patch may also be found that is usually small, barren and sandy, often round in shape but sometimes

Table 4 Analytical Data for Pits 1-3 in Ban Khum Phaya (Modified after Takaya *et al.* [1985])

Pit No.	Sampling Depth (m)	pH	EC (μ℧/cm)	Total Extractable Bases (meq/100 g soil)	Na/Total Base (%)	Cl⁻ Content	Carbonate	Clay Mineralogy
1	0.3	6.5	38	1.58	38.6	—	—	Kaol.>Mt.
	0.6	5.9	44	1.12	30.4	—	—	Kaol.>Mt.
	0.9	6.8	98	2.14	88.8	—	—	Kaol.>Mt.
	1.1	7.6	174	6.70	57.2	±	—	Kaol.>Mt.
	1.5	8.1	270	7.80	80.8	±	—	Mt.>Kaol.
	1.8	8.1	270	9.98	63.1	±	—	Mt.>Kaol.
	2.2	8.0	380	12.26	63.3	+	—	Mt.>Kaol.
	2.5	8.1	440	15.23	62.1	++	—	Mt.>Kaol.
	3.2	8.1	450	23.95	63.5	++	—	Mt.>Kaol.
2	0.5	6.5	24	0.38	10.5	—	—	Kaol.>Mt.
	1.2	6.3	43	1.35	28.1	—	—	Kaol.>Mt.
	1.6	7.3	450	12.51	57.8	+	—	Mt.>Kaol.
3	0.2	9.3	440	6.05	26.4	±	—	Mt.>>>Kaol.
	0.5	9.4	610	36.14	24.1	++	—	Mt.>>>Kaol.
	0.7	9.4	710	28.35	26.8	++	++	Mt.>>>Kaol.

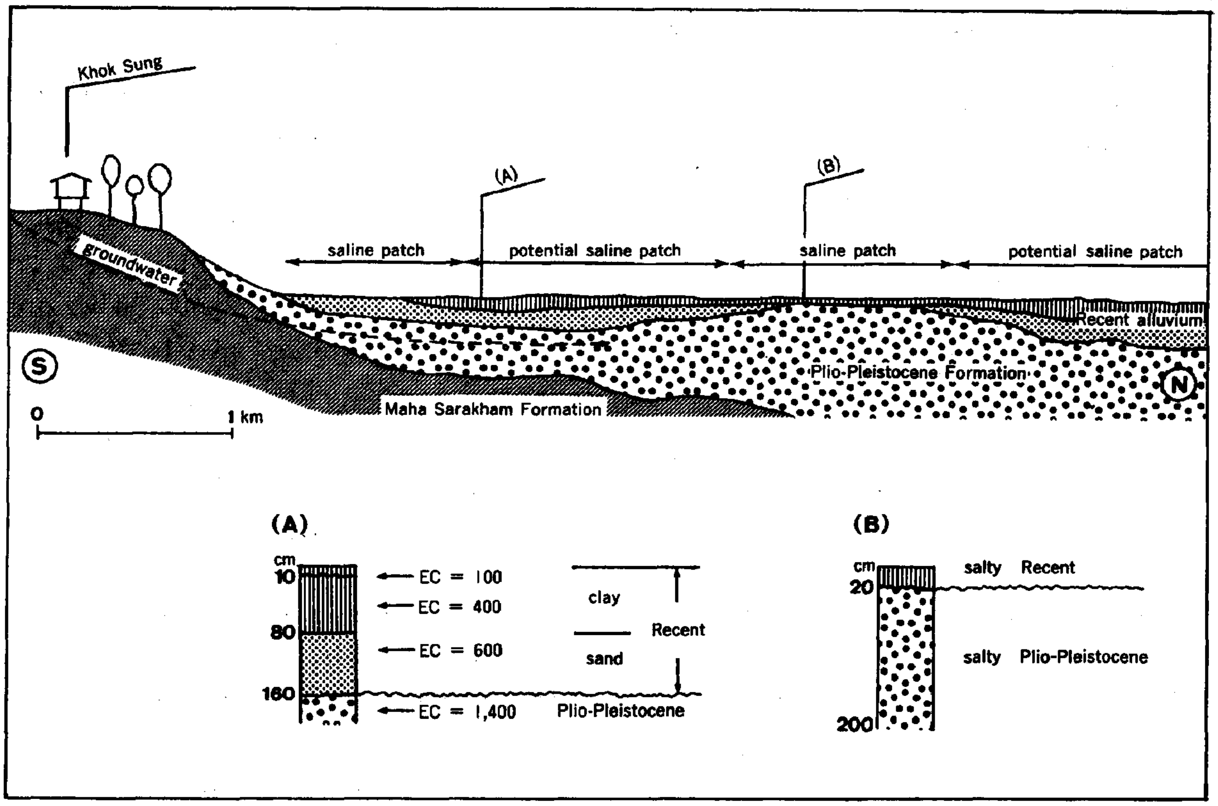

Fig. 14 A Schematic N-S Cross Section at Ban Khok Sung along the Cho Ho – Non Thai Road to Show Brine Flow beneath Cap-clay (Modified after Takaya *et al.* [1985])

Table 5 Description of the Two Profiles Shown in Fig. 14 (Modified after Takaya *et al.* [1985])

Profile	Depth (cm)	Lithology	pH	EC (μ℧/cm)	Total Extractable Bases (meq/100 g soil)	Na/Total Base (%)	Cl^- Content	Carbonate	Clay Minerals
A	0-10	Grayish brown (10YR 5/2) sandy loam	6.0	100	—	—	—	—	—
	10-80	Light gray (10YR 6/1) sandy loam with common brown(7.5YR 4/6) cloudy mottles and occasional calcareous nests	—	400 at 50 cm depth	—	—	—	—	—
	80-160	Light olive gray (2.5GY 7/1) loamy clay with many brownish yellow (10YR 6/6) and yellowish brown (10YR 6/8) cloudy mottles	9.2	620	18.97	28.2	++	—	Mt.>Kaol.
	160-200	Light greenish gray (7.5GY 7/1) clay with common brownish yellow (10YR 6/8) cloudy mottles and many manganese pisoliths	8.6	1,400	22.18	32.3	+++	—	Mt.>Kaol.
B	0-20	Brownish gray (10YR 5/1) sandy clay loam, salty	—	—	—	—	—	—	—
	20-200	Grayish yellow-brown (10YR 6/2) to light gray (10YR 7/1) sandy loam with many large yellowish brown (10YR 5/8) mottles and common large (3-7cm) carbonate nodules, salty	—	—	—	—	—	—	—

an elongated strip. They mostly occur on sandy ground surfaces where an uneven sandy layer of Recent alluvium rises to the surface, causing a different stratification from that shown in Fig. 14, while the surrounding paddy fields have a clayey ground surface. The mechanism of salinization is similarly capillary rise. Fig. 15 is a schematic distribution and cross section of these sandy saline patches.

The northern bank of the Mun River between Amphoe Non Sung in the west and Amphoe Chum Phing in the east, stretching from 102° 15′E to 102° 45′E (Fig. 16), has a broad, flat, low-lying topography that is easily mistaken for a Recent alluvial plain. Certainly, there are Recent alluvial deposits in the area, but they are not as thick or as continuously developed as would be expected from the underlying Plio-Pleistocene Formation or Maha Sarakham Formation (Table 6). These older formations shallowly underlying the Phimai Plain are a direct source of salt, and the possibility of salinization of the ground surface when the capping layer is removed is extremely high.

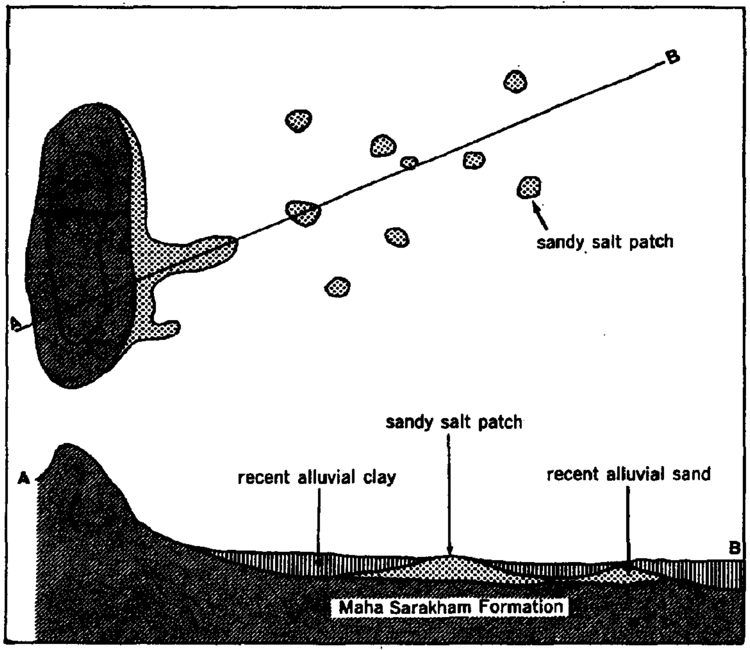

Fig. 15 Schematic Aerial Distribution of Sandy Salt Patches and Its Underground Structure (Modified after Takaya *et al.* [1985])

3. *The Basin Area* (*Thung Kula Ronghai*)

Loeffler *et al.* [1983] have presented a standard stratigraphy of the Thung Kula Ronghai within a depth of 35 m from the ground surface. It is composed of (1) clay, (2) nonorganic sand, (3) organic sand, and (4) lower nonorganic sand, from the surface downwards. The organic sand is dated at about 30,000 years old.

While agreeing with the dating, Takaya *et al.* [1985] believe that the Recent alluvial deposits

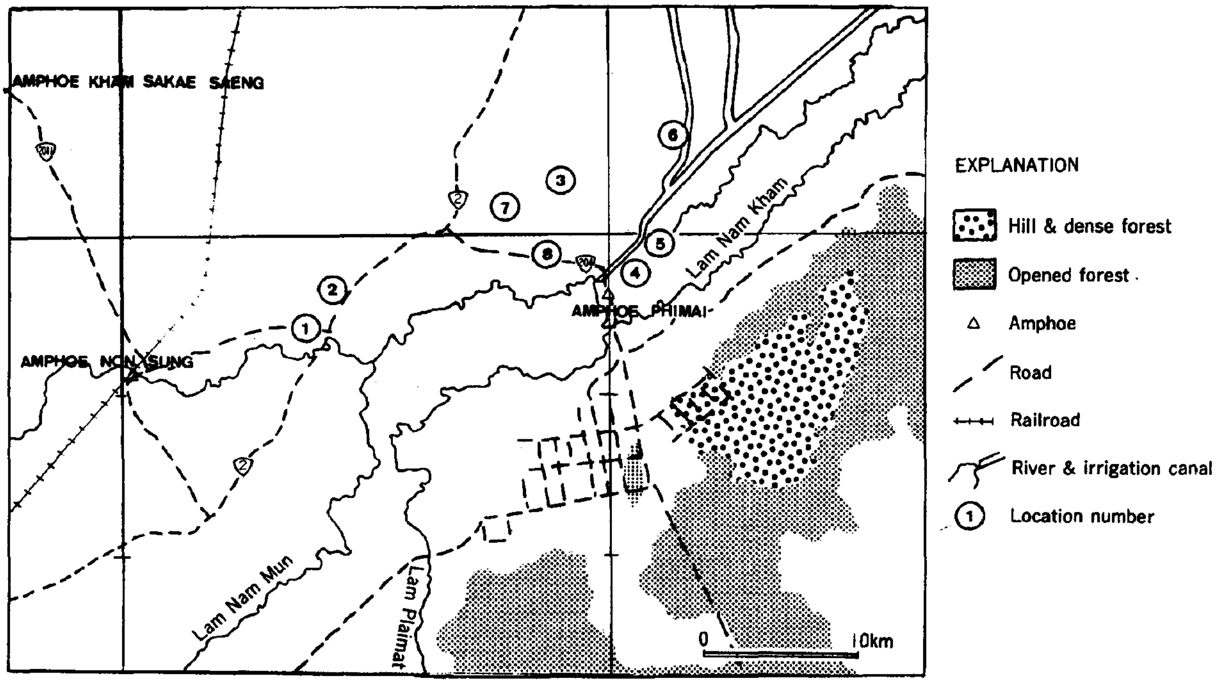

Fig. 16 A Location Map of the Phimai Plain, and Locations of the Maha Sarakham Formation and/or the Plio-Pleistocene Formation (Modified after Takaya *et al.* [1985])

Table 6 Descriptions of the Maha Sarakham Formation and Plio-Pleistocene Formation in the Phimai Plain, Shown in Fig. 16 (Modified after Takaya *et al.* [1985])

Loc. No.	Site	Depth (m)	Lithology	pH	EC (μ℧/cm)	Cl^- Content	Rock Formation
1	A dug pond at the southern edge of Ban Yaa Kha	0-0.7	2.5Y gray sandy clay loam with 10YR yellow mottlings and large (less than 10 cm) carbonate nodules	—	—	—	Plio-Pleistocene Formation
		0.7-1.0	Red siltstone				Maha Sarakham Formation
2	Roadside ditch, 42 km from Nakhon Ratchasima along the Khorat - Khon Kaen highway	0-0.3	Fe-pisolith-bearing sandy loam	8	600	—	Plio-Pleistocene Formation
		0.3-2.6	10YR and 2.5Y gray sandy clay loam with many 10YR yellow mottlings and few large (3-10 cm) carbonate nodules				
3	Ban Toei	0-2.0	Disturbed soil. Debris of fragments of snails and earthenware, especially Phimai black pottery	—	—	—	—
		72.0	Red siltstone, with thin capping veneer of laterized gravel bed	7.5	4,000	卌	Maha Sarakham Formation
4	1 km west of Phimai along the main road	0-1.0	Dull brown (7.5YR 6/3) silty clay loam with 7.5YR brown filmy and fibrous mottles	—	—	—	Recent alluvium
		1.0-1.3	10YR gray sandy loam with many 10YR large yellow mottles and common large (3-20 cm) carbonate nodules				Plio-Pleistocene Formation
5	Canal bank, 1 km east of Phimai along the RID's main canal	0-0.4	Dark gray sandy loam	7	—	—	Recent alluvium
		0.4-1.0	Dull yellow brown (10YR 4/3) sandy loam with many Fe-pisoliths	8	—	—	Upper Pleistone Formation
6	Ban Nong Muang, about 9 km NE of Phimai	1.0-2.0	Grayish yellow (2.5Y 7/2) loamy sand with large bright yellowish brown (10YR 6/8) mottles and large (3-7 cm) carbonate nodules	8.3	—	—	Plio-Pleistocene Formation
7	Broadcast paddy fields between the Phimai road and Ban Toei	2.0-2.5	Bluish gray sandy clay loam	—	—	—	—
8	Ban Tamyan	2.5-2.6	Quicksand	—	—	—	—

in this area do not reach as deep as 35 m. Many parts of the so-called Thung Kula Ronghai are indicated by the following evidence to be underlain by the Plio-Pleistocene Formation at depths as shallow as 1 to 1.5 m.

1) Outcrops at many places, particularly places with close stands of *sabang* trees, have well-indurated and heavily weathered sediments that are often capped

by a thin lateritic layer such as is usually found on older sediments than the Middle Pleistocene.

2) Tektite has been found 18 km east of Amphoe Phayakkhaphum Phisai along the Phayakkhaphum Phisai – Kaset Wisai road. Though the location is not in the middle of Thung Kula Ronghai, it is within the flat, low-lying basin of the Thung Kula Ronghai.

Examination, moreover, of a core sample obtained from a deep well at Suwannaphum shows that sand and gravel are the major sediment down to 350 feet (120 m). Below that is red sandstone and halite. There are also traces of sulfur-like material at a level between 300 and 350 feet below the ground surface. This 350-foot layer of sand and gravel is too thick to be simply Recent alluvial deposits and must also represent Plio-Pleistocene deposits. It is also too thick for brine to rise through, as indicated by the fact that the brine rise is only 50 feet. Therefore, the thick halite deposit at the bottom of this basin lies too deep to be a source of soil salinity.

The source of the salt in Thung Kula Ronghai must be in the hills to the north of the basin. The isolated hills scattered between the Lam Tao and the Lam Phlappha are also potential sources. The mechanism of salinization is the same as in the flat valley area: salt released from the hills is carried into the lowland by interflow. Where it is received there develop saline spots or potential saline spots, depending on the depth of the interflow and the permeability of the capping clay.

The number of hillocks of the Maha Sarakham Formation in Thung Kula Ronghai is much larger than would be expected from its topography. This confirms that this large, flat basin should not be treated as an alluvial plain in the strict sense. Rather, it is classified as a broad Plio-Pleistocene surface with Recent alluvial patches and scattered Maha Sarakham hillocks.

IV Probable Mechanism of Salinization

The mechanism of salinization in the Khorat Plateau is not as complex as might be imagined, because the plateau is actually a rather small, closed basin. All sediments on the plateau are erosion-weathering products of the basement with no outside materials. The geologic setting, especially the dipping angle of the basement, is another factor in salinization insofar as it controls the topographic and groundwater gradients. Shallow-lying direct sources of salt, i.e., the Maha Sarakham Formation and the Plio-Pleistocene Formation, seem to be the most important factors in salinization in the plateau, because they are readily susceptible to erosional and weathering pressures.

Although the mechanism of salinization in the Khorat Plateau is simple, differences exist from place to place which are closely related to topography and salt-source exposure. In general, however, the mechanism is short-distance interflow of brine in the salt-source layers, particularly the Plio-Pleistocene Formation, together with capillary rise of brine.

Interflow must be of short distance

because the Khorat Plateau is actually not a plain throughout. There is evidence that it contains many small sub-basins, which are surrounded by scattered exposures or have shallow-lying beds of salt-source rock formations. At times of heavy rain and during the rainy season, salt is eroded or weathered from the salt-source rock formations and transported by surface flow, or leached into the groundwater. Brined surface water and brined groundwater thus flow through the sub-basins and accumulate locally. When the ground surface is dry enough, salt will precipitate from the brined surface water or rise as brined groundwater.

The degree of capillary rise differs with different materials, depending on the closeness of grain packing, and thus being lowest in gravel and highest in clay. Brined groundwater in the plateau is present in the salt-source rock formations, usually in the clayey layer of the Plio-Pleistocene Formation, and this is often of low permeability. Therefore, the brined groundwater gradient is low enough for brine to be supplied to the upper layer. Salt may not appear on the ground surface, however, if the layer overlying the brine-saturated layer is too thick to be permeated by capillary rise. This means that the thickness of the overburden is another factor closely associated with capillary rise in the appearance of surface salt.

Conclusion

There are three potential sources of the surface salt in the Khorat Plateau.

1) The Rock Salt Member of the Maha Sarakham Formation. Composed mainly of halite with lesser amounts of anhydrite, and containing salt-free as well as rock-salt strata, this member is a huge salt-source wherever a salt-bearing stratum is exposed or lies near the ground surface.

2) The Upper Clastic Member of the Maha Sarakham Formation. This is composed mainly of very fine-grained clastic sediments, i.e., semi-consolidated clay to claystone/mudstone. It had previously been classified as salt-free, but indications have been found of salt in the sediment of this member, making it a potential source of surface salt.

3) The Plio-Pleistocene Formation. This consists entirely of clay that usually shows a distinctive white to light gray matrix with brownish yellow mottles. Montmorillonite is a major clay mineral in the clay fraction. The reported presence of sulfur and gypsum together with high pH are evidence of salt content in this formation. Whether this salt is syngenetic or post-genetic, its presence makes the Plio-Pleistocene Formation another potential source of surface salt.

Areas of surface salt in the Khorat Plateau are broadly classified into three on the basis of their topographic and geologic settings: hill, valley, and basin.

1) Salinity in the hill area is closely related to the salt-bearing rock, the Rock Salt Member of Maha Sarakham Formation, that underlies the area. Salt appears either directly on the salt-bearing or in foothills due to seepage.

2) Salinity in the valley area is

precipitated from brine that is carried by either surface or subsurface water. Brine interflow under cap clay is the major mechanism of salt supply. The valley floor is usually covered by thin Recent alluvium overlying sediments of the Plio-Pleistocene Formation.

3) Salinity in the basin area is represented by that in Thung Kula Ronghai. There, the sources of salt are the shallow-lying Plio-Pleistocene Formation and scattered, isolated hills to the north. These hills are remnants of the Maha Sarakham Formation. For this reason, the Thung Kula Ronghai should not be treated as an alluvial plain but as a broad Plio-Pleistocene surface with Recent alluvial patches and scattered Maha Sarakham hillocks.

The mechanism of salinization in the Khorat Plateau is short-distance interflow of brine in the salt-source layers, accompanied by capillary rise. In the heavy rain of the rainy season, salt is eroded and weathered from the salt-source formations and transported by surface flow or leached into the groundwater. Brined surface water and brined groundwater flow through the small sub-basins of the plateau, sometimes accumulating locally. When the ground surface is dry enough, salt precipitates from the brined surface water or rises from the brined groundwater.

References

Borcharat, G. A. 1977. Montmorillonite and Other Sonoctite Minerals. *Minerals in Soil Environments*. Wisconsin: Soil Science Society of America. pp. 293–325.

Dixon, J. B. 1977. Kaolinite and Serpentine Group Minerals. *Minerals in Soil Environments*. Wisconsin: Soil Science Society of America. pp. 357–398.

Hattori, T.; Yonebayashi, K.; and Kyuma, K. 1979. Intercalation Index with Hydrazine, Morphology and Surface Microtopography of Kaolinite Clays in the Tropical Asian Soils. *Soil Sec. Plant Nutr.* 25(3): 425–436.

Loeffler, E.; Thompson, W. P.; and Liengsakul, M. 1983. Geomorphological Development of the Thung Kula Ronghai. *Proceedings of the 1st Symposium on Geomorphology and Quaternary Geology of Thailand*. pp. 123–130.

McGowan International PTY LTD. 1983. *Thung Kula Ronghai Salinity Study*. Thai-Australia Thung Kula Ronghai Project. pp. 28–118.

Mekong's Secretariat. 1978. *Notes on Geological, Geomorphological and Structural Features of the Khorat Plateau Including Particularly the Nam Mun and Nam Chi Basins*. Bangkok: Interim Committee for Coordination of Investigations of the Lower Mekong Basin. pp. 1–65, Map.

Michael, P. 1981. Landforms, Surface Sediments and Associated Soil Units in Nakhon Ratchasima Province, Thailand: A Land-Surface Survey and an Interpretation on the Geologic Genesis of the Khorat Plateau's Upland Soils. *Tech. Bull.* 31: 1–106, Map. Bangkok: Soil Survey Division.

Pramojanee, P.; and Panichapong, S. 1984. The Geomorphological Map of the Northeastern Part of Thailand. *Tech. Bull.* 57: 1–14, Map. Bangkok: Soil Survey and Classification Division.

Sinanuwong, S.; and Takaya, Y. 1974a. Saline Soils in Northeast Thailand. *Southeast Asian Studies* 12(1): 105–120.

————. 1974b. Distribution of Saline Soils in the Khorat Basin of Thailand. *Southeast Asian Studies* 12(3): 365–382.

Takaya, Y.; Hattori, T.; and Pichit. 1985. Soil Salinization in the Khorat Plateau. Original Paper Submitted to Mekong's Secretariat. pp. 1–37.

Wongsomsak, S. 1985. Geomorphology and Land Use in Northeast Thailand: A Case Study Changwat Buri Ram. M. S. Thesis, Kyoto University, Kyoto. pp. 44–69.

Yumuang, S. 1983. On the Origin of Evapolite

Deposits in the Maha Sarakham Formation in Barmnet Narong Area, Changwat Chaiyaphum. M. S. Thesis, Chulalongkorn University, Bangkok. pp. 26–172.