CHAPTER II

GEOLOGY AND LITHOSTRATIGRAPHY

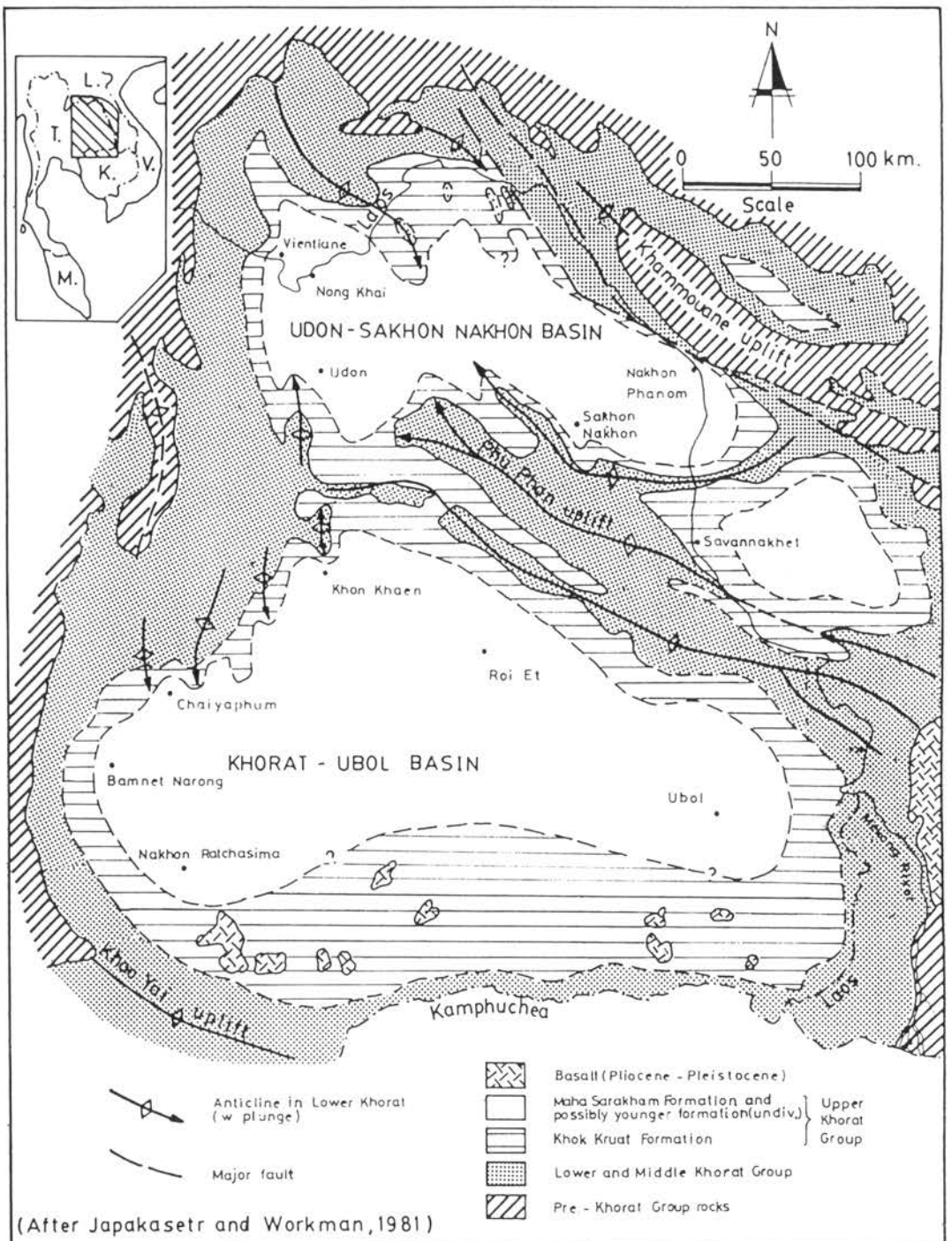
In order to fully understand the origin of evaporite deposits in the Maha Sarakham Formation under the present investigation, it is considered that the geological setting of the region as well as detailed local geology including sub-surface geology of the study area must be well established. The regional geology and stratigraphy of the Khorat Plateau has been compiled exclusively out of previous investigation up to 1982. In addition, detailed sub-surface information from the drilling exploration and laboratory studies has been carried out under the present study.

Factual information obtained from the present study is presented in this chapter. Besides, additional attempt has been made to define and describe in detail the lithostratigraphy of rock sequences from the ground surface down to the approximate depth of 465 meters.

2.1 Geology of the study area

2.1.1 Regional geology and stratigraphy of Khorat Plateau

The Khorat Plateau covers an area of about 170,000 square kilometers in northeastern Thailand and central Laos. It forms a large blocklike platform between two structurally complex orogenic belts which trend north-south along its east and west boundaries. The Phu Phan uplift or anticlinorium trends east-west across the plateau and divides it into the Khorat-Ubol Basin on the south and the Udon-Sakhon Nakhon Basin on the north (Figure 2.1.1.1).



(After Japakasetr and Workman, 1981)

GENERALIZED GEOLOGICAL MAP OF NORTHEAST THAILAND	On the Origin of Evaporite Deposits in the Maha Sarakham Formation in Bamnet Narong Area, Changwat Chaiyaphum	
DEPARTMENT OF GEOLOGY, GRADUATE SCHOOL CHULALONGKORN UNIVERSITY, 1983	SOMBAT YUMUANG	FIG. 2.1.1.1

The Khorat Plateau is essentially underlain by a considerable thick sequences of Mesozoic and Cenozoic sediments. The consolidated sediments which are widely distributed in the Khorat Plateau of northeastern Thailand belong to the Khorat Group. Lithologically, the Khorat Group consists mainly of the typical red-bed facies of clastic rocks. In addition, several cycles of marine evaporites and carbonate sediments have been found interbedded in some formations of the Khorat Group. Generally, the Khorat Group rests unconformably on the Paleozoic rocks.

Numerous workers have attempted to subdivide the Khorat Group into several formations, and these stratigraphical subdivisions have been summarized and presented in Table 2.1.1. Here, particular emphasis has been focussing upon the upper formations of the Khorat Group, notably, Khok Kruat Formation, and Maha Sarakham Formation.

The lower and middle formations of Khorat Group are extensively exposed along the margin of the Khorat Plateau as well as along the Phu Phan mountain range. Within the two structural basins of Udon-Sakhon Nakhon Basin and Khorat-Ubol Basin of the Khorat Plateau, the Khok Kruat Formation is thoroughly exposed along the basinal margins whereas the Maha Sarakham and posibly younger formations occupy the central parts of the basins, covering the areas of about 21,000 square kilometers in Udon-Sakhon Nakhon Basin and 36,000 square kilometers in the Khorat-Ubol Basin. It is also noted that in the southern margin of the Khorat-Ubol Basin, Pliocene-Pleistocene basalts are found extruded the Khok Kruat Formation in several localities.

Table 2.1.1 Stratigraphical subdivision of the Khorat Group (modified after Ramingwong, 1978)

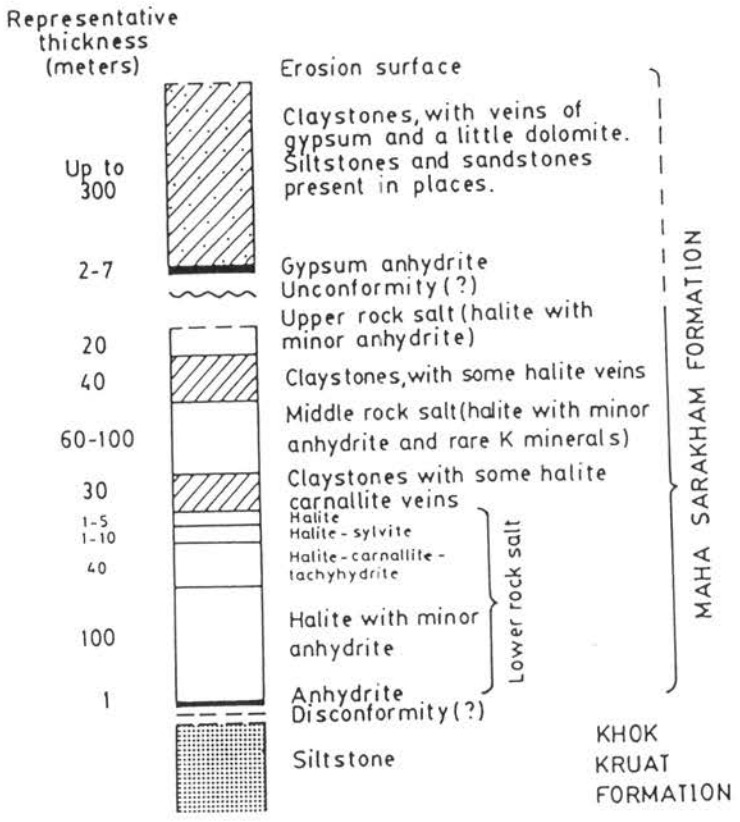
La Moreaux and others (1959)		Ward and Bunnag (1964)		Iwai and others (1968)	Borax and Steward (1965)		Iwai and others (1975)			Workman (1977)		Dept. Min. Resources (1982)	
Unnamed				Lom Sak Fm.			Lom Sak Fm.			Salt (Maha Sarakham) Fm.		KHORAT GROUP	Maha Sarakham Fm.
		KHORAT GROUP	Khok Kruat Fm.	Ban Na Yo Fm.	Upper		Ban Na Yo Fm. S1	Ban Na Yo Fm. S.STR	Nam Phung Fm.	Ban Na Yo (Khok Kruat) Fm.			Khok Kruat Fm.
KHORAT SERIES	Phu Phan member		Phu Phan Fm.	Phu Phan Fm.	Middle	Upper Resistant Sandstone	Phu Phan Fm.			Phra Wihan Fm.	Phra Wihan member		Phu Phan Fm.
	Phra Wihan Fm.		Sao Khua Fm. Phra Wihan Fm.	Phra Wihan Fm.		Intermediate member Lower Resistant Sandstone	Phra Wihan Fm.				Sao Kua member		Sao Kua Fm.
											Lower Phra Wihan member		Phra Wihan Fm.
	Phu Kradung Fm.		Phu Kradung Fm.	Phu Kradung Fm.	Lower Lake bed (?) Locally Basal conglomerate		Phu Kradung Fm.			Phu Kradung Fm.	Upper Phu Kradung member		Phu Kradung Fm.
			Nam Phong Fm.	Huai Hin Lat Fm.			Nam Pha	Huai Hin Lat Fm.			Nam Phong member		Nam Phong Fm.
													Huai Hin Lat. Fm.

The Khok Kruat Formation is overlain by the Maha Sarakham Formation where evaporites deposited in a vast basin probably established in Late Cretaceous time (Japakasetr and Workman, 1981). Lithologically, the Maha Sarakham Formation consists mainly of evaporites interbedded with claystones. The upper of the formation is characterized by the claystones, with veins of gypsum, small amount of dolomite, and siltstones and sandstones in places with total thickness up to 300 meters. The total thickness of the Maha Sarakham Formation is up to 650 meters. For Khok Kruat Formation, the lithology is mainly sandstone, siltstone and shale, with some limestone and conglomerate. The percentage of sandstone in the succession decreases from about 60 near the base to about 20 near the top (Workman, 1972). The diagrammatic columnar section of the Maha Sarakham Formation and the upper part of the Khok Kruat Formation is presented in Figure 2.1.1.2.

2.1.2 Geology of the study area

The study area, with an areal extent of approximately 170 square kilometers, lies near the western border of the Khorat Plateau in the northwest corner of the Khorat-Ubol Basin. The topography of the area is characterized by the flat plain in the central part with minimum elevation of 194 meters above the mean sea level. Bordering the central flat plain on the northern, eastern, and southern parts are broad undulating terrains with relief of approximately 30 meters. On the eastern and southeastern parts of the central flat plain are gentle sloping hills with maximum elevation of approximately 240 meters above the mean sea level.

The study area is in most parts underlain by the Quaternary alluvium, namely, flood plain, alluvial sands and silt, and backswamp



(After Japakasetr and Workman, 1981)

DIAGRAMMATIC COLUMNAR SECTION THROUGH MAHA SARAKHAM FORMATION	On the Origin of Evaporite Deposits in the Maha Sarakham Formation in Bamnet Narong Area, Changwat Chaiyaphum	
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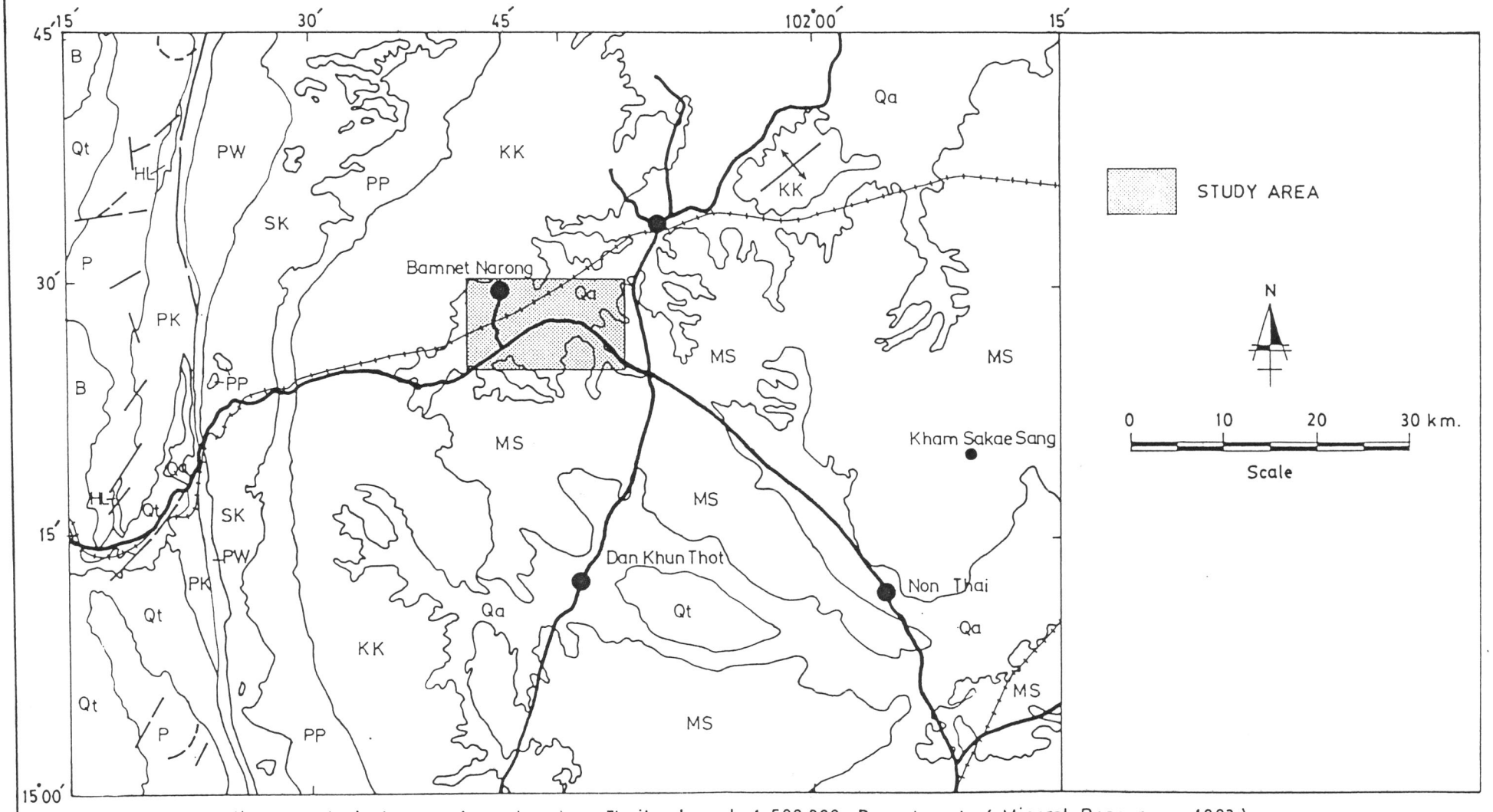
deposits. The Khok Kruat Formation occupies only the small area in the most northern and northwestern parts of the area, whereas the Maha Sarakham Formation is extensively exposed in the southern and eastern part. However, almost all of the area presently overlain by the Quaternary deposits is the rocks of the Maha Sarakham Formation. The thickness of the Quaternary deposits varies within the range of 1-60 meters. The geological map of the study area (Figure 2.1.2.1) is based on the unpublished geological map of northeastern Thailand with 1 : 500,000 scale by the Department of Mineral Resources, 1982.

Besides, evidence of the Bouguer gravity map of the study area (Figure 2.1.2.2) with 1 : 1,000,000 scale and 1.0 mgal contour interval indicates that all contour values are negative. Generally, the gravity shows an increasing pattern of about 5 mgal northeastwardly within a 20 - kilometer distance. However, there are many areas of anomalously gravity low and high scattering over the eastern part out of the study area.

Detailed sub-surface geology of the study area is being discussed in the foregoing part.

2.2 Lithostratigraphy

Generally, the sub-surface lithostratigraphy of the study area is essentially based on the lithological analysis, mineralogical and textural determination, chemical as well as geophysical characteristics of the sedimentary sequences from the ground surface down to the depth range of 60-465 meters. Consequently, it is apparent that the complete lithostratigraphic sequences (Figure 2.2.1) of the Maha Sarakham Formation of the Khorat Group can be subdivided into several rock members,



(After the unpublished geological map of northeastern Thailand, scale 1:500,000 , Department of Mineral Resources , 1982)

GEOLOGICAL MAP OF THE STUDY AREA	On the Origin of Evaporite Deposits in the Maha Sarakham Formation in Bamnet Narong Area, Changwat Chaiyaphum	SOMBAT YUMUANG DEPARTMENT OF GEOLOGY GRADUATE SCHOOL CHULALONGKORN UNIVERSITY, 1983	FIG. 2.1.2.1

EXPLANATION OF FIGURE 2.1.2.1

B = Basalt (Quaternary)

Q_a = Recent flood plain, alluvial sands, silt, back swamp deposits, beach sand.

Q_t = Terrace gravel, sand, silt, laterite and lateritic soil.

MK = Siltst, shale, sandstone, brick red, purplish red, weathered white to grey, thin to thick bedded; with rock salt, potash, gypsum and anhydrite.

KK = Sandstone, brown, reddish brown, partially micaceous; shale; siltstone, pale brown, pebbly, micaceous; with some lime-noduled conglomerate.

PP = Sandstone, white, pale orange; sandstone, pale orange, yellowish brown, pebbly, cross-bedded; with some shale and conglomerate.

SK = Sandsone, reddish brown, grey, micaceous; siltstone, grey, brown; lime-nodules conglomerate; purplish brown, brick red.

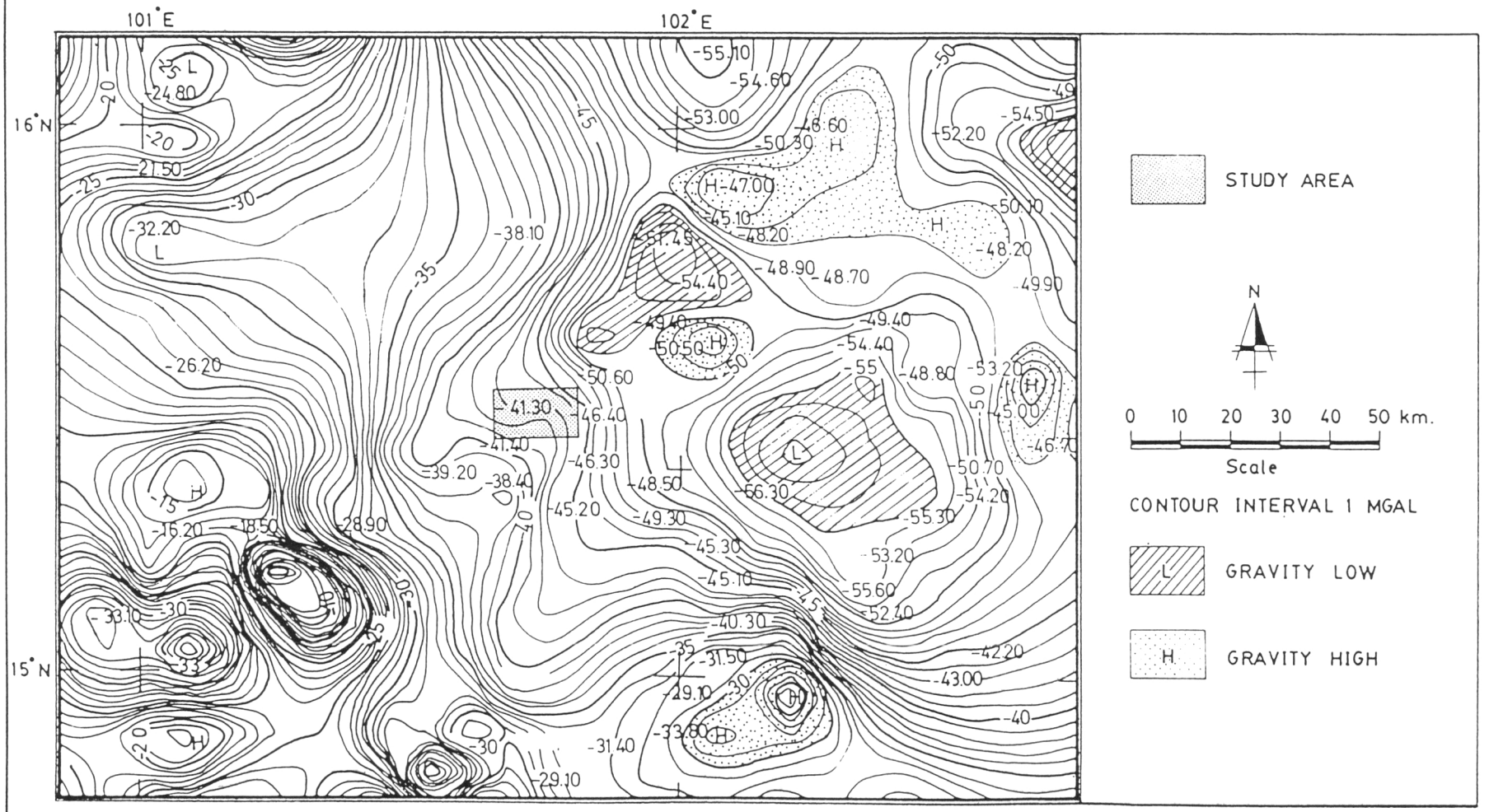
PW = Sandstone, white, pink, cross-bedded, massive, pebbly layering at the upper beds; with some reddish brown and grey shale.

PK = Shale, brown, reddish brown, purplish red, micaceous; siltstone, sandstone, brown, grey; with some lime-nodules conglomerate.

HL = Conglomerate; shale, grey, black; mudstone, grey, calcareous; limestone, argillaceous; sandstone, yellowish brown.

P = Limestone, light to dark grey, bedded to massive with fossils; shale, red, grey to black, carbonaceous, calcareous, laminated to thick bedded with fossils; sandstone, yellowish brown, bedded to massive, lense; chert, black, noduled or thin bedded; siltstone, conglomerate, mudstone, sandy shale; micaceous sandy siltstone; tuffaceous sandstone; tuff; andesitic tuff; agglomerate; rhyolite; andesite.

/ major faults



(After ESSO , 1979)

BOUGUER GRAVITY MAP OF THE STUDY AREA	On the Origin of Evaporite Deposits in the Maha Sarakham Formation in Bamnet Narong Area, Changwat Chaiyaphum	SOMBAT YUMUANG DEPARTMENT OF GEOLOGY GRADUATE SCHOOL CHULALONGKORN UNIVERSITY 1983	FIG. 2.1.2.2

LITHOSTRATIGRAPHY OF BAMNET NARONG AREA , CHANGWAT CHAIYAPHUM .

GROUP	FORMATION	MEMBER	BED		THICKNESS (m.)	GENERAL LITHOLOGIES
?	?	Alluvium			1.00-20.00	Yel gry to brn uncons cly,sd and some gvl.
?	?	Upper Clastics			13.24-316.08	Rd brn & grn gry semi-cons cly to clst/mdst intbd with calc clst/mdst and some sltst/ss.
KHORAT	MAHA SARAKHAM	Upper Salt	Upper Cap Anhydrite	uc	0-7.01	Lt gry anhy.
			Upper Upper Halite		0-30.16	Clear,milky wh m gr halite and smoky dk halite bands with anhy layers.
			Upper Anhydrite	u	0-1.05	Dk to lt gry anhy.
			Lower Upper Halite		0-13.08	Clear m gr halite & smoky dk halite bands,pale honey to orng halite associated.
		Middle Clastics	Middle Mudstone/Claystone		8.94-53.00	Rd brn & grn gry to dk gry semi-cons cly to clst/mdst.
		Middle Salt	Middle Cap Anhydrite	mc	0-6.15	Lt gry anhy.
			Upper Middle Halite		1.46-95.33	Clear&milky wh f to m gr halite and smoky dk halite bands with anhy layers,some gry&pale orng halite associated in the upper part
			Middle Anhydrite	m	0.11-2.04	Dk gry to lt gry anhy.
			Lower Middle Halite		10.94-22.17	Pale yel brn to orng&dk honey f gr halite with smoky dk halite bands.
		Lower Clastics	Lower Mudstone/Claystone		1.68-25.76	Rd brn & grn gry to dk gry semi-cons cly to clst/mdst.
		Basal Salt	Coloured Halite		0.28-15.90	Several col bands of halite.
			Potash: Sylvinite		0-5.11	Cloudy wh,orng rd sylvite
			Potash: Carnallite,Halite&Tachyhydrite		1.25-65.87	Pale pk,pk clear to orng rd carnallite & clear and smoky dk halite & orng to honey yel tachyhydrite intbd and mixed.
			Potash: Sylvinite		0-0.22	Cloudy wh,orng rd sylvite.
			Basal Halite		21.66-191.44	Clear f gr halite. Clear f to m gr halite with anhy layers. Clear & milky wh m to c gr halite and smoky dk halite bands with anhy layers. Clear f to m gr halite & smoky dk halite bands,wh dull f to m gr anhy associated.
			Basal Anhydrite	b	0.77-1.86	Dk gry to lt gry anhydrite
			Calc Sandstone		0.07-1.10	Grn gry calc ss.
	KHOK KRUAT?		Ferrugenous Sandstone		5.18	Dk rd brn Fe ss.

LITHOSTRATIGRAPHY OF THE STUDY AREA

On the Origin of Evaporite Deposits in the Maha Sarakham Formation in Bamnet Narong Area, Changwat Chaiyaphum

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FIG. 2.2.1

namely, Basal Salt, Lower Clastics, Middle Salt, Middle Clastics, and Upper Salt. However, the uppermost two members, notably, Upper Clastics and Alluvium should be arranged under another different rock formation. It is also interesting to note that almost complete evaporitic sequences are present only in the Basal Salt Member of the Maha Sarakham Formation.

The incomplete lithostratigraphic sequences (Figure 2.2.2) of the Maha Sarakham Formation of the Khorat Group in some localities consists mainly of Basal Salt Member with incomplete evaporitic sequences. Besides, the uppermost Clastics Members rest local-unconformably (?) on the Basal Salt Member.

The synthesis of the sub-surface geology of the study area is illustrated in lithostratigraphic cross-sections (Plates 1 to 6), structural contour maps, as well as isopach maps of major stratigraphic units. Location of cross-sections of the study area is presented in Figure 2.2.3. Generally, the Maha Sarakham Formation in the study area is located at small depth and thickening toward the central part as well as in the northern part. In contrast, this formation gradually appears much deeper and thinner toward the southeastern and the northeastern parts of the study area. (Plates 1 to 6) It is noted that the shallow and thick sequences of the Maha Sarakham Formation in the central and northern parts of the study area are mainly controlled by the gentle salt anticlinal structures that are always associated with the incomplete lithostratigraphic sequences. Furthermore, this incomplete sequences of the Maha Sarakham Formation is generally unconformably (?) overlain by members of another rock formation..

INCOMPLETE STRATIGRAPHIC SEQUENCES IN THE STUDY AREA

GROUP	FORMATION	MEMBER	BED		THICKNESS (m.)	GENERAL LITHOLOGIES
?	?	Alluvium			3.05-60.96	Yel brn & gry uncons to semi-cons sd,clayey sd,gvl and some cly.
?	?	? Upper Clastics & Middle Clastics & Lower Clastics ?			12.19-53.96	Rd brn & grn gry semi-cons cly to clst/mdst intbd with clst/mdst & some sltst/ss.
			Anhydrite/Gypsum		0-10.77	Wh to dk gry anhy/gypsum.
					5.06-17.90	Rd brn & grn gry to dk gry semi-cons cly to clst/mdst.
?- - - -	?- - - -					~~ Local Unconf ? ~~
KHORAT	MAHA SARAKHAM	Basal Salt	Basal Cap Anhydrite	bc	0-28.75	Lt to dk gry anhy/gypsum, poor cemented.
			Basal Halite	L L L	37.38-295.22	Clear & milky wh m to c elongated gr halite and smoky dk halite bands,absent or rare anhy layers (mostly high angle dipping in the upper part and decreased to lower angle dipping along depth). Clear f to m gr halite and smoky dk halite bands,with wh dull f to m gr anhydrite associated.
			Basal Anhydrite	b	0.77-1.86	Dk gry to lt gry anhydrite.
			Calc Sandstone		0.07-1.10	Grn gry calc ss.
	?- - - - KHOK KRUAT?	?- - -	Ferrugenous Sandstone		> 5.18	Dk rd brn Fe ss.

INCOMPLETE LITHOSTRATIGRAPHIC SEQUENCES IN THE STUDY AREA

On the Origin of Evaporite Deposits in the Maha Sarakham Formation in Bamnet Narong Area,Changwat Chaiyaphum

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FIG. 2.2.2

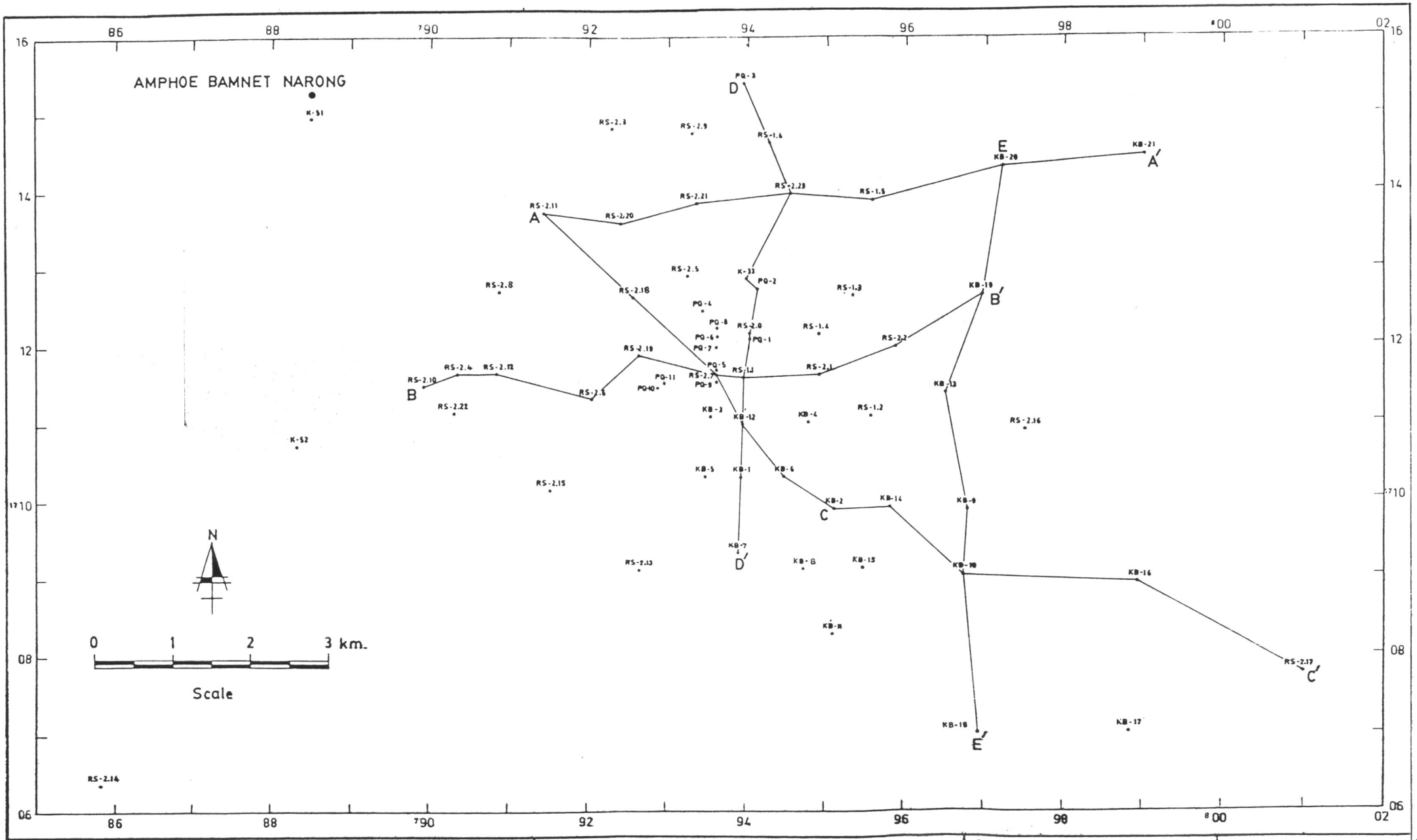

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FIG. 2.2.3

Besides, the complete sequences of the Maha Sarakham Formation is generally present at localities where the formation is thin and appears at a relatively greater depth. However, the Maha Sarakham Formation gradually gently dips toward the southeast of the study area. In addition, it is very interesting to note that the thickening zones of the sequences, especially of the incomplete sequences of the Basal Salt Member, are usually associated with the salt anticlinal structures in the area. (Plates 1 to 6)

Detailed sub-surface geology of the study area is being discussed, from the lower part to the upper part of the sequence as follows :

2.2.1 Basal Salt Member

The Basal Salt Member, containing almost complete evaporitic sequences of the Maha Sarakham Formation, has been divided into seven Beds as described below :

a) Ferrugenous Sandstone Bed

The Ferrugenous Sandstone Bed is considered as the base of the Maha Sarakham Formation in the study area. This Bed may be categorized as the uppermost part of the Khok Kruat Formation. Its thickness is unable to identify due to the limited depth of the drill-holes. However, it should be over 5 meters in thickness. Besides, the Bed is found extensively throughout the study area and normally has nearly horizontal gradational contact with the overlying Calcareous Sandstone Bed.

b) Calcareous Sandstone Bed

The Calcareous Sandstone Bed is extended throughout the study area despite the fact that it is very thin. The thickness varies within

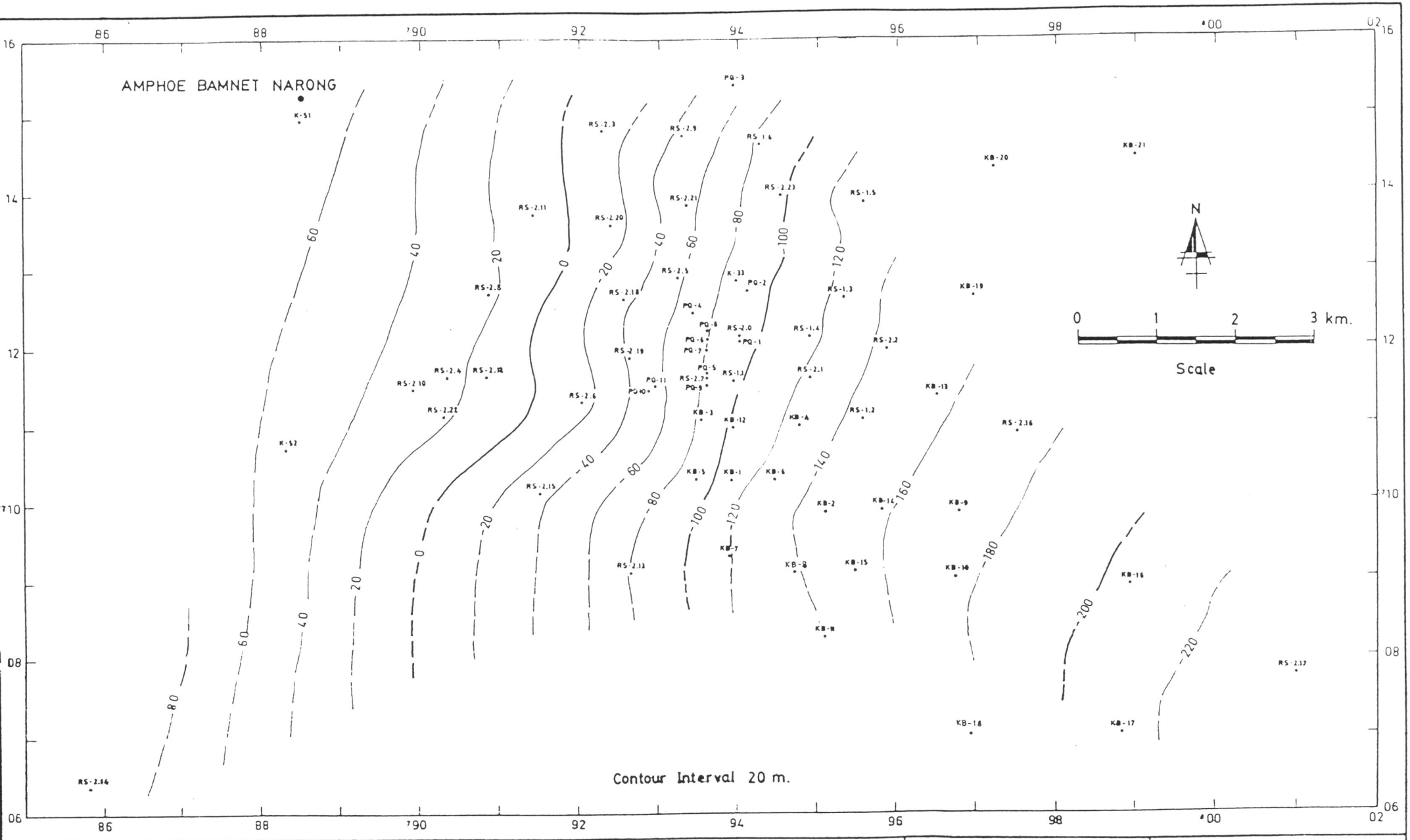
the range of 0.07-1.10 meters but commonly in a relatively much narrow range of 0.20-0.60 meter. The depth to the top of the Bed gradually increases to southeastwardly within the depth range of 60 meters above the mean sea level to 220 meters below the mean sea level (Figure 2.2.1.b). From the stratigraphic cross-sections (Plates 1 and 2) the Bed is generally very gentle dipping (less than 15°) to the southeast direction of the study area. Generally, the contact with the overlying Basal Anhydrite Bed is in nearly horizontal sharp plane.

c) Basal Anhydrite Bed

The Basal Anhydrite Bed, similar to the underlying Calcareous Sandstone Bed, is found extensively throughout the study area although it is very thin. The thickness varies within the range of 0.77-1.86 meters but commonly in a relatively much narrow range of about 0.90-1.30 meters. The depth to the top of Bed gradually increases southeastwardly similar to the underlying Calcareous Sandstone Bed (Figure 2.2.1.c.1). Generally, the Bed is rather thin in the central part of the area with a tendency to increase in thickness in the surrounding outer zone (Figure 2.2.1.c.2). From the stratigraphic cross-sections (Plates 1 and 2), the Bed is very gentle dipping to the southeast direction conformable with the underlying Calcareous Sandstone Bed. Besides, the contact with the overlying Basal halite Bed is nearly horizontal to very high-angle dipping sharp plane with the complete and incomplete sequences of Basal Halite Bed, respectively.

d) Basal Halite Bed

The Basal Halite Bed, the major part of the Basal Salt Member, is found extensively throughout the study area. The thickness varies



STRUCTURAL CONTOUR MAP ON TOP OF CALCAREOUS SANDSTONE BED OF BASAL SALT MEMBER

On the Origin of Evaporite Deposits in the Maha Sarakham Formation in Bamnet

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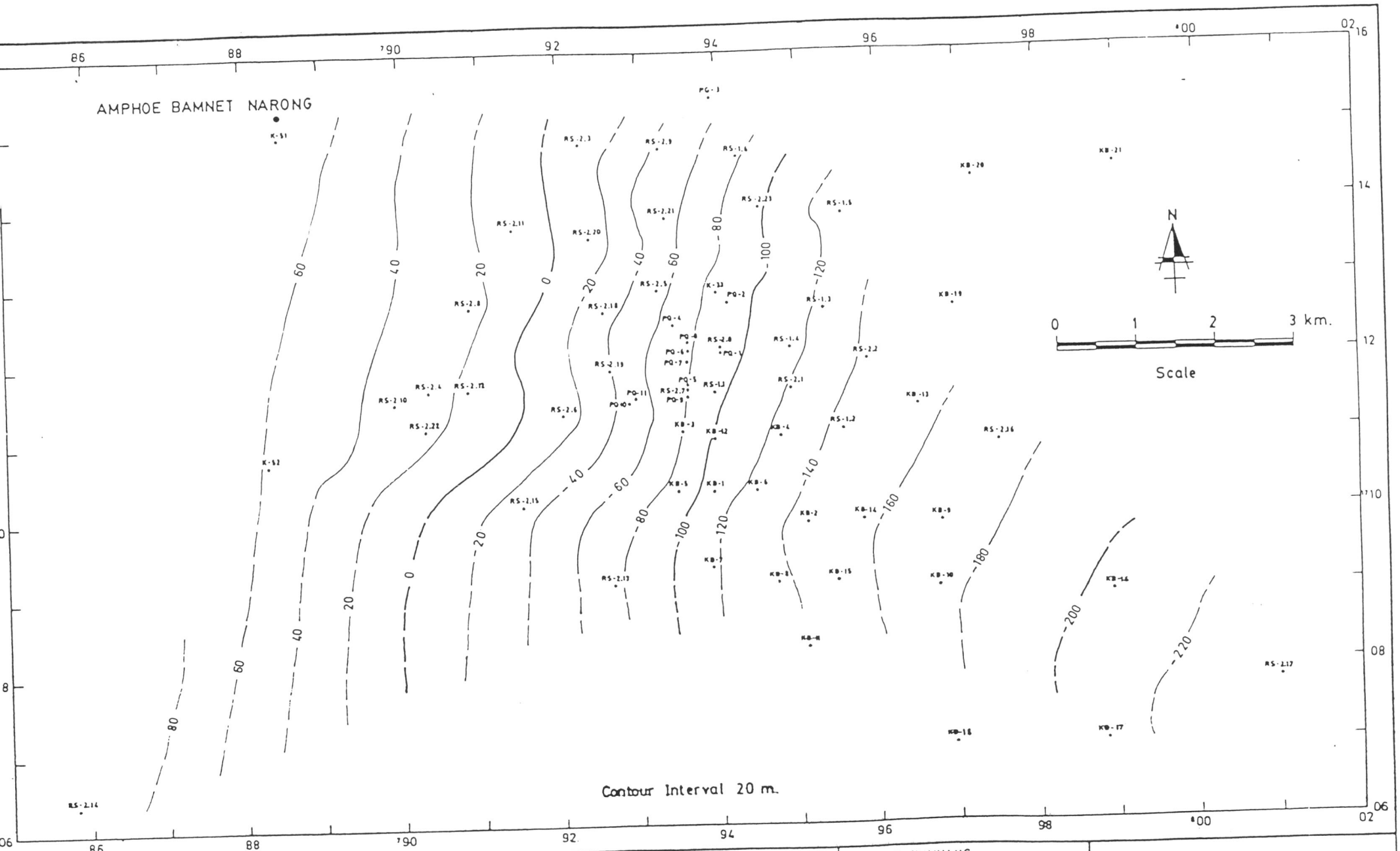
FIG. 2.2.1.b



STRUCTURAL CONTOUR MAP ON TOP OF BASAL

On the Origin of Evaporite Deposite in the Maha Sarakham Formation in Bamnet

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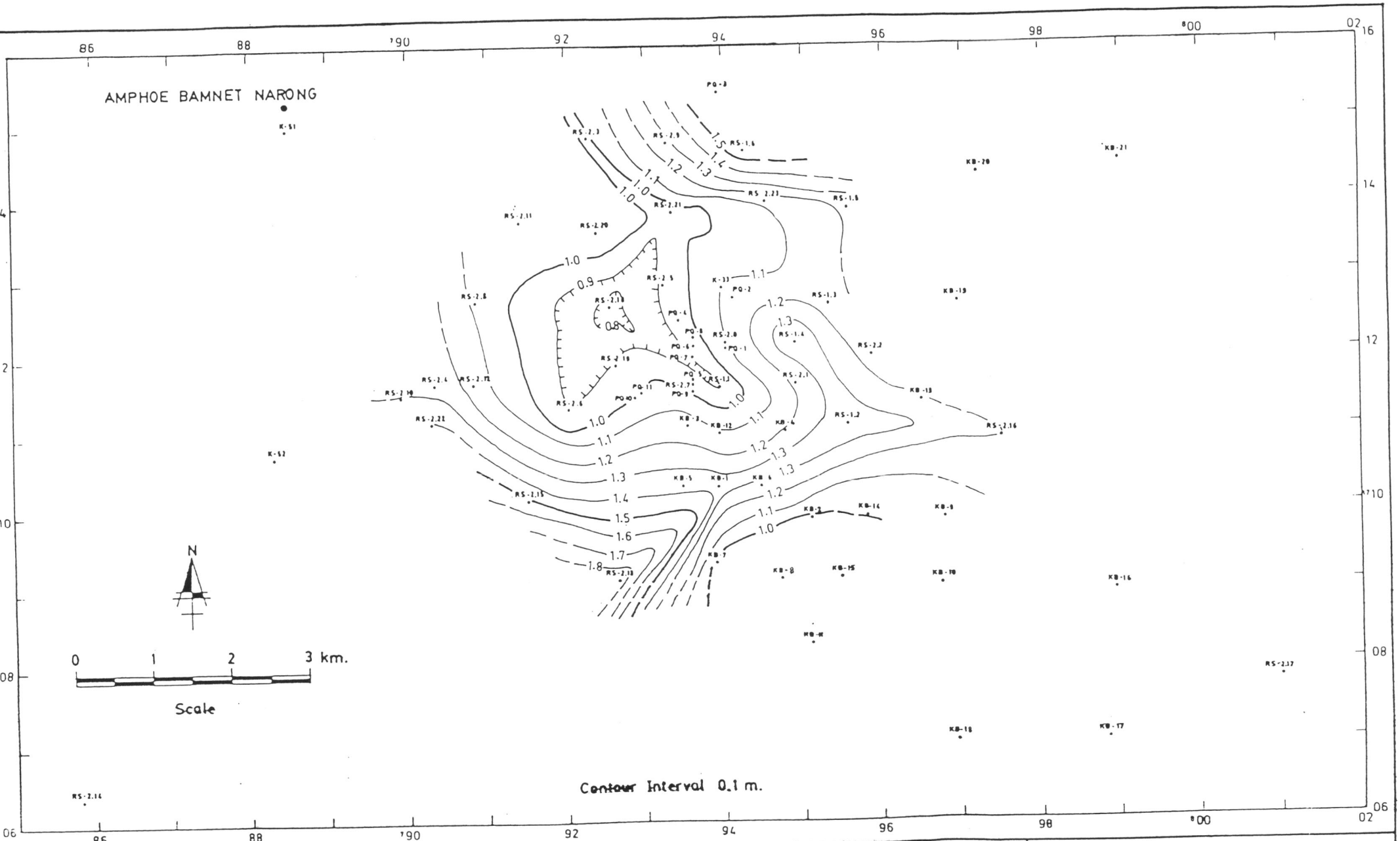
FIG. 2.2.1.c.1



ISOPACH MAP OF BASAL ANHYDRITE

On the Origin of Evaporite Deposits in the Maha Sarakham Formation in Bamnet

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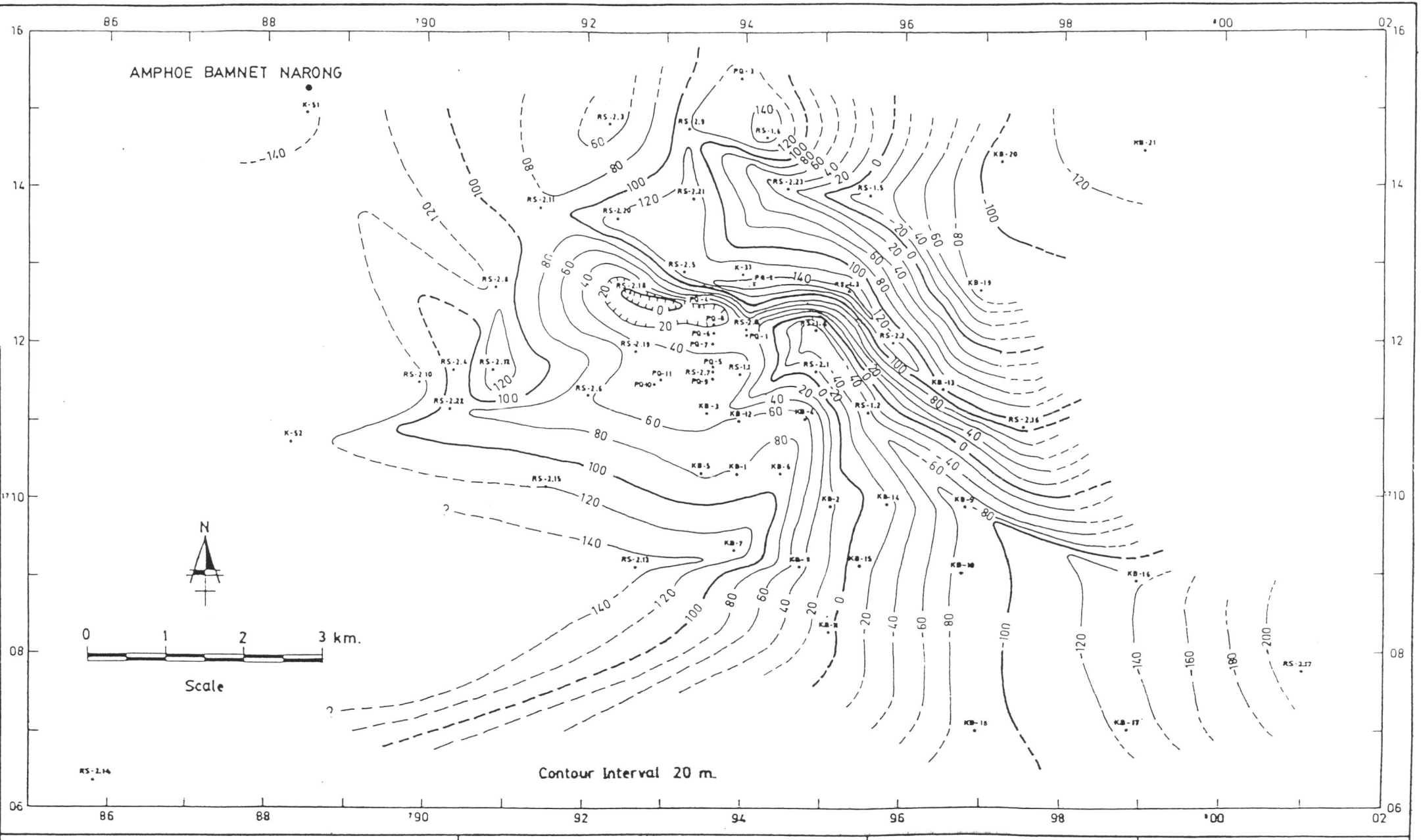
FIG. 2.2.1.c.2

within the range of 21.66-191.44 meters in the complete lithostratigraphic sequences, but varies from 37.38-295.22 meters in the incomplete sequences within the study area. The depth to the top of the Bed generally increases southeastwardly within the depth range of 140 meters above the mean sea level to 200 meters below the mean sea level. Besides there is a gentle salt anticlinal structure in the northwest - southeast trend extending from the northern part to the eastern part of the study area (Figure 2.2.1.d.1). Besides, the thickness of the Bed also increases southeastwardly and the thickest part of the Bed is generally associated with the salt anticlinal zones (Figure 2.2.1.d.2). From the stratigraphic cross-sections (Plates 3, 4, 5 and 6), the salt anticlines in the study area are rather gentle dipping and are usually associated with the incomplete sequences of the Bed.

It is noted that the Bed is in nearly horizontal and has the gradational contact with the overlying Potash Bed of the complete sequences of Basal Salt Member. However,it is in nearly horizontal sharp contact with the overlying rocks, commonly the Basal Cap Anhydrite Bed, of the incomplete sequences of Basal Salt Member.

e) Potash Bed

The Potash Bed contains the highest order evaporites of the Basal Salt Member. It is found in limited areal extent of the study area and always absent in the salt anticlinal zones. Besides, the depth to the top of the Bed generally increases southeastwardly within the depth range of 120 meters above the mean sea level to 200 meters below the mean sea level (Figure 2.2.1.e.1). The thickness varies within the range of 1.25-71.20 meters and the thickest part of the Bed is present in the lower central part of the study area with a tendency to be thinner



STRUCTURAL CONTOUR MAP ON TOP OF BASAL HALITE BED OF BASAL SALT MEMBER

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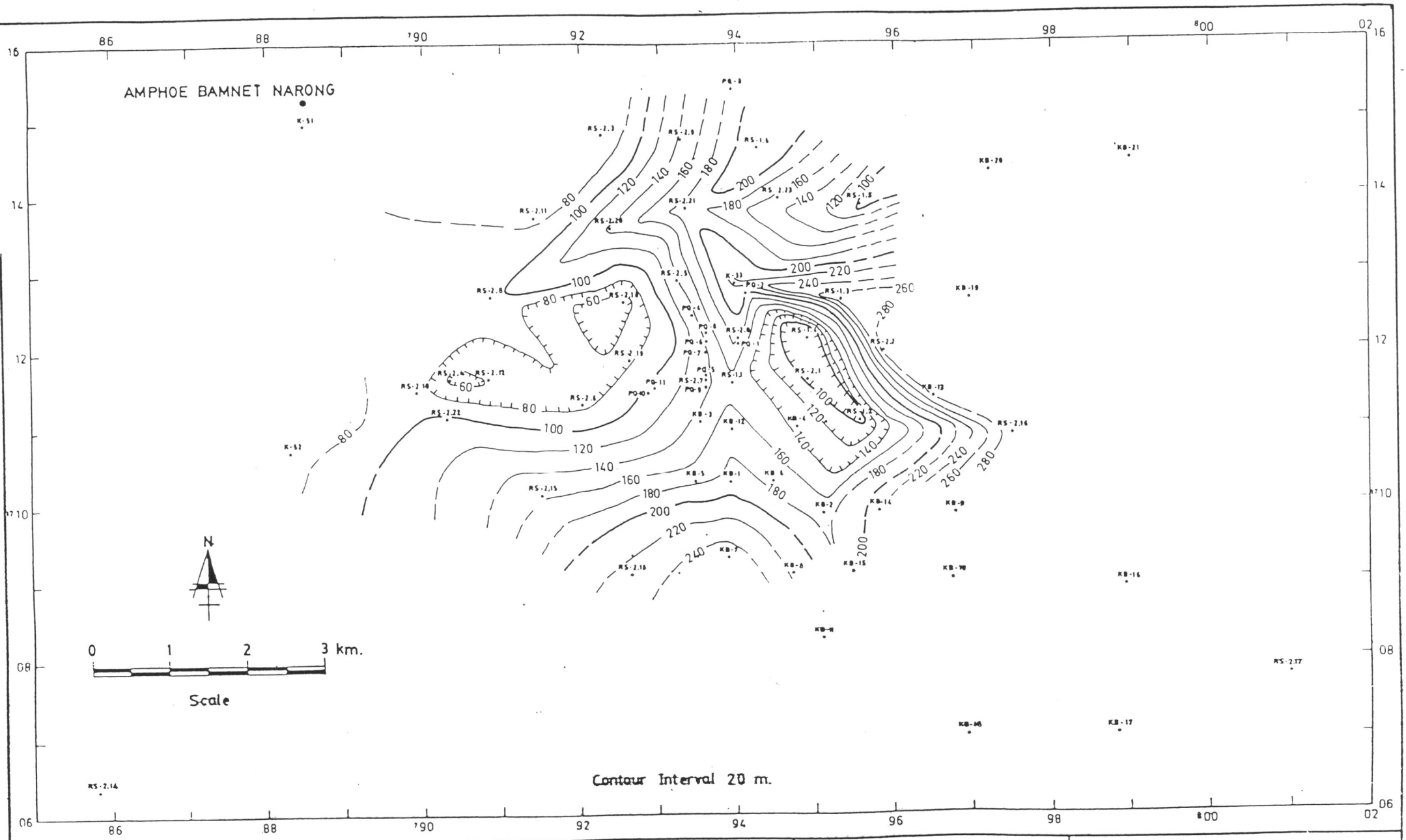
FIG. 2.2.1.d.1



ISOPACH MAP OF BASAL HALITE BED

On the Origin of Evaporite Deposits in the Maha Sarakham Formation in Bamnet

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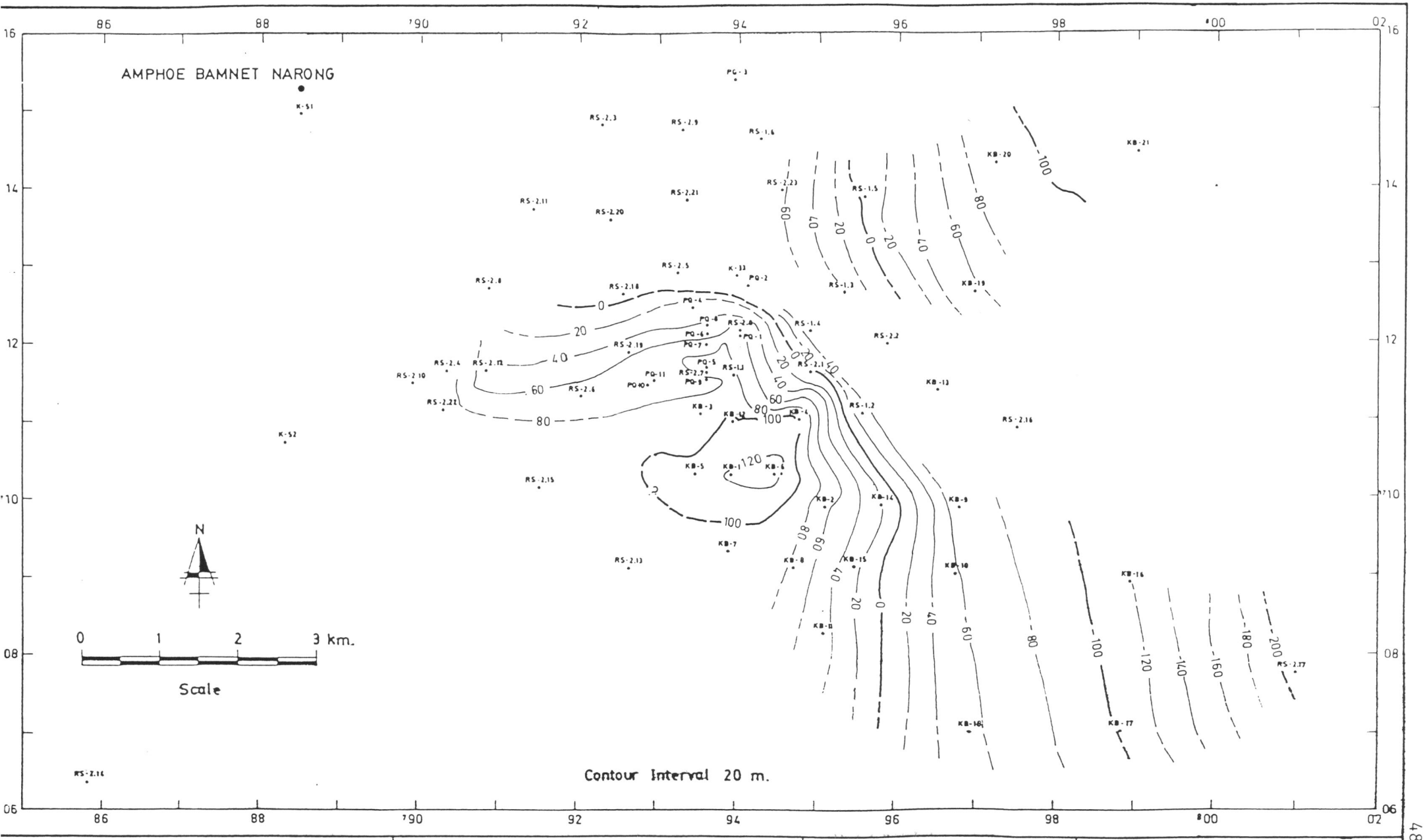
FIG. 2.2.1.d.2



STRUCTURAL CONTOUR MAP ON TOP OF POTASH BED OF BASAL SALT MEMBER

On the Origin of Evaporite Deposits in the Maha Sarakham Formation in Bamnet

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FIG. 2.2.1.e.1

in the surrounding outer part, especially in the southwestern part of the study area (Figure 2.2.1.e.2). The contact with the overlying Coloured Halite Bed is commonly of nearly horizontal gradational type. However, if the Sylvinite sub-bed is present within the Bed, the bedding plane has rather higher dipping angle up to 55°.

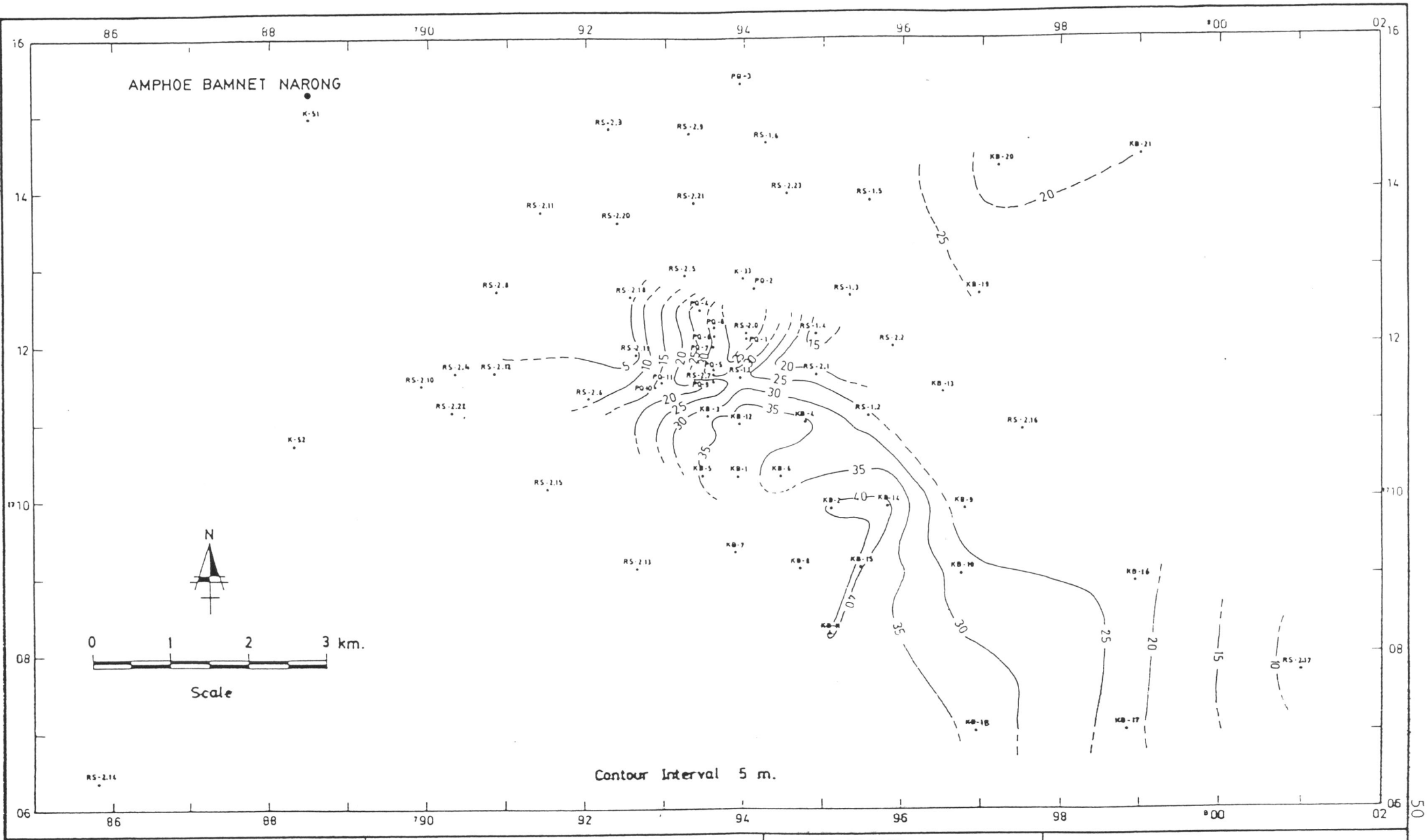
Generally, the Potash Bed is subdivided into three Sub-Beds, notably, the lower Sylvinite, Carnallite - Halite - Tachyhydrite, and the upper Sylvinite Sub-Beds. The Carnallite - Halite - Tachyhydrite Sub-Bed, the most common Sub-Bed commonly present in the Potash Bed, varies in thickness in the range of 1.25-65.87 meters. Besides, the lower and upper Sylvinite Sub-Beds are locally present in the study area with their thicknesses of about 0-0.22 and 0-5.11 meters, respectively. The distribution of the Potash Bed is clearly illustrated in the litho-stratigraphic cross-sections of the study area (Plates 1 to 6).

f) Coloured Halite Bed

The Coloured Halite Bed is the uppermost bed in the complete sequences of the Basal Salt Member. The thickness varies within the range of 0.28-15.90 meters but normally narrow ranging of about 0.60-2.10 meters. Besides, the depth to the top of the Bed is generally conformable with the underlying Potash Bed because of its nearly uniformly thickness (Figure 2.2.1.f). It is noted that the contact with the overlying Lower Clastics Member is in nearly horizontal gradational plane.

g) Basal Cap Anhydrite Bed

The Basal Cap Anhydrite Bed is usually present in the uppermost part of the incomplete sequences of the Basal Salt Member, as well as associated with the salt anticline zones of the study area (Plates 3 to 6).



ISOPACH MAP OF POTASH BED OF BASAL SALT MEMBER

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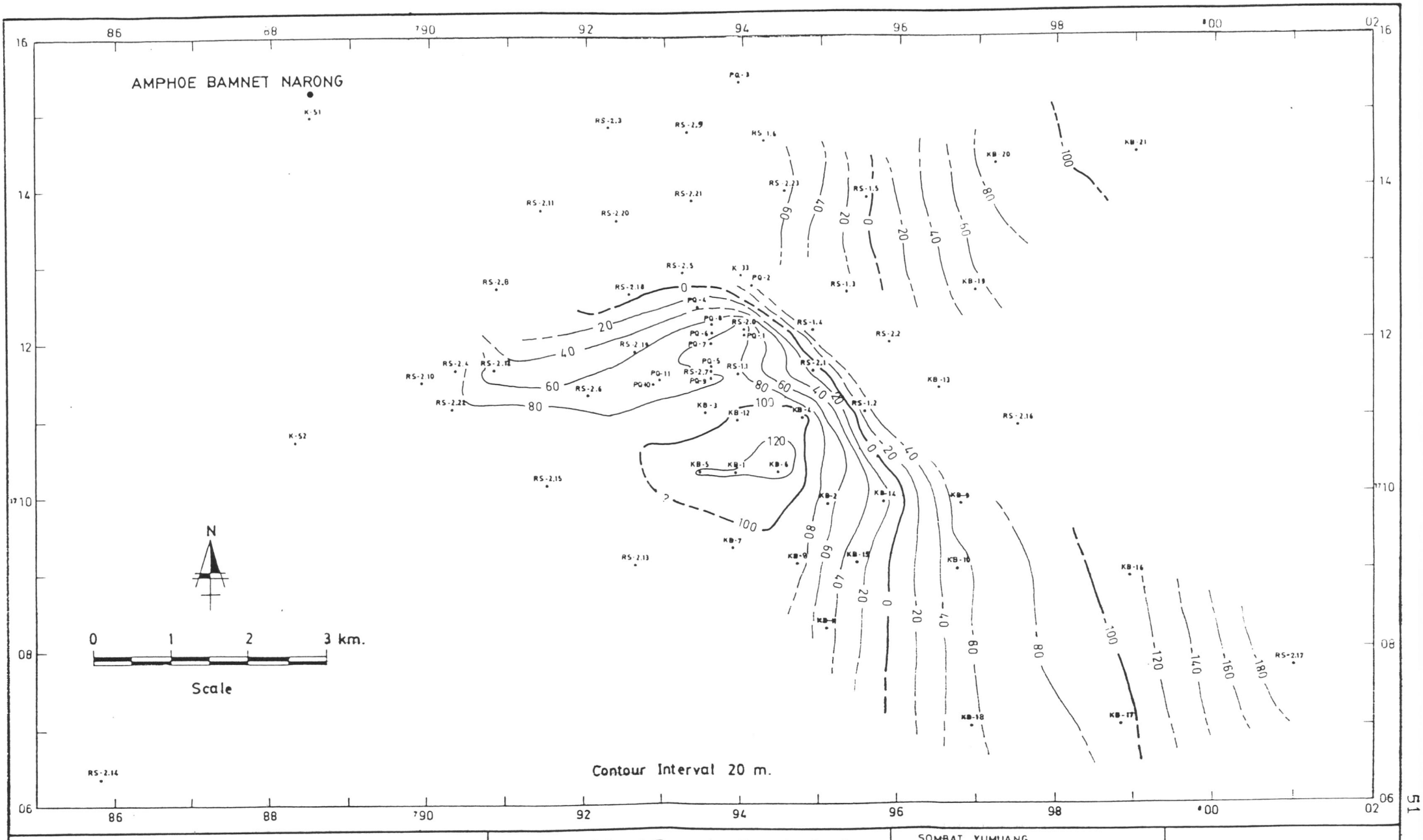
FIG. 2.2.1.e.2



STRUCTURAL CONTOUR MAP ON TOP OF COLOURED HALITE BED OF BA II SALT MEMBER

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FIG. 2.2.1.f

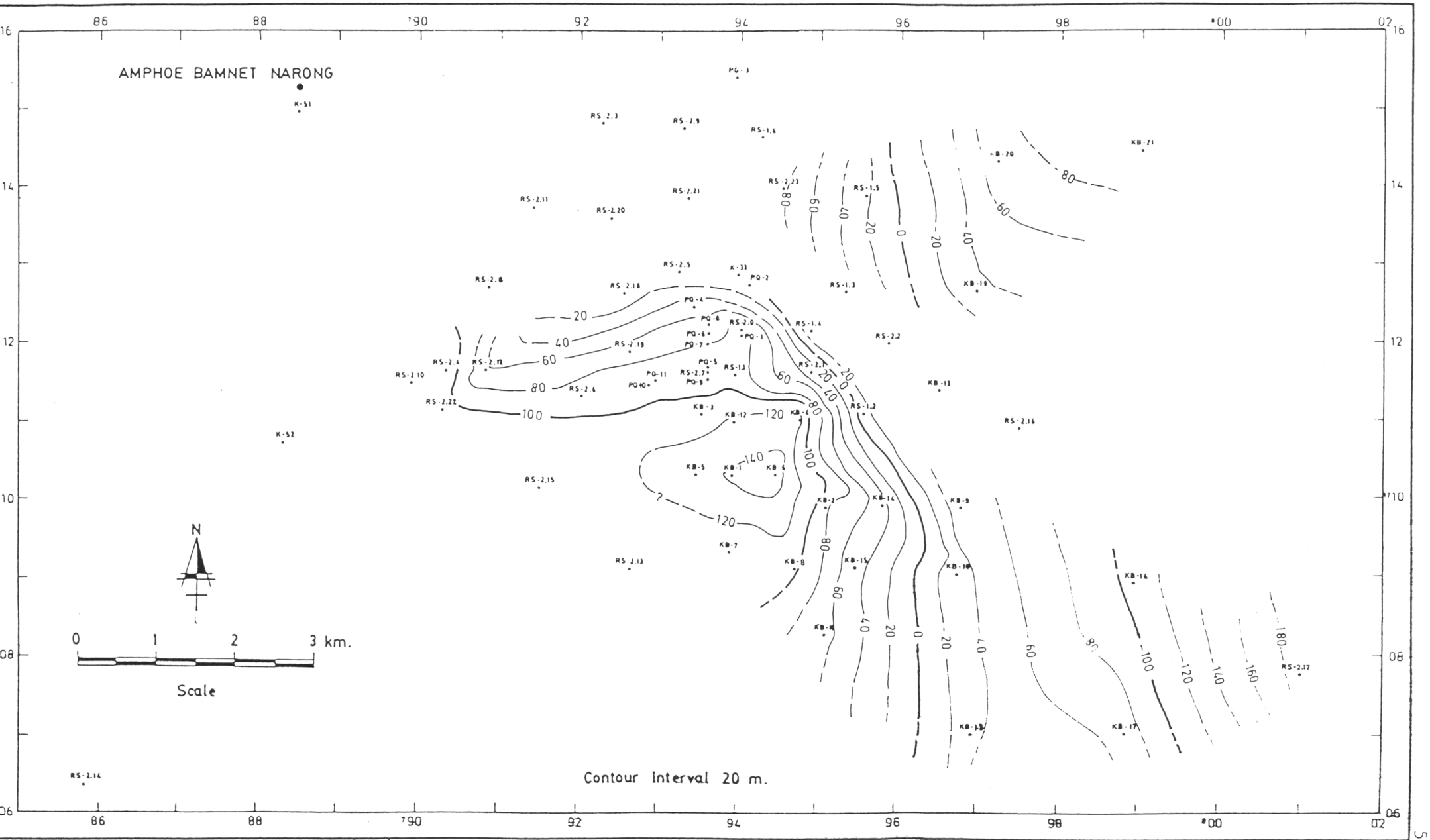
Generally, its thickness varies within the range of 0-28.75 meters. From the stratigraphic cross-sections, the thickest part of the Bed is present along the crest of the gentle salt anticline area. Besides, the contact with the overlying Clastics Member is the sharp plane with 20^{o}-40^{o} dipping angle.

2.2.2 Lower Clastics Member

The Lower Clastics Member lies most distinctively between the Coloured Halite Bed of the complete sequences of the Basal Salt Member and the Middle Salt Member with nearly horizontal gradational contact. It is noted that the Member is hardly to be seperated from the overlying Clastics Members (?) in the salt anticline zones. Generally, the thickness of the Member varies within the range of 1.68-25.76 meters. The depth to the top of the Member generally increases from the central part to the surrounding outer part, especially to southeastward, within the depth range of 140 meters above the mean sea level to 180 meters below the mean sea level (Figure 2.2.2.1). However, the structure on top of this Member is mainly conformable with that of the underlying Coloured Halite Bed of the complete sequences of Basal Salt Member. Besides, the thickness of the Lower Clastics Member varies from place to place in the central part of the study area, except in the eastern lower part of the area where the thickest zone of this Member generally decreases southeastwardly (Figure 2.2.2.2). The distribution of the Lower Clastics Member is illustrated in the stratigraphic cross-sections (Plates 1 to 6)..

2.2.3 Middle Salt Member

The Middle Salt Member that consists essentially of halite is generally less clear than in the Basal Salt Member. This member always



STRUCTURAL CONTOUR MAP ON TOP OF LOWER CLASTICS MEMBER

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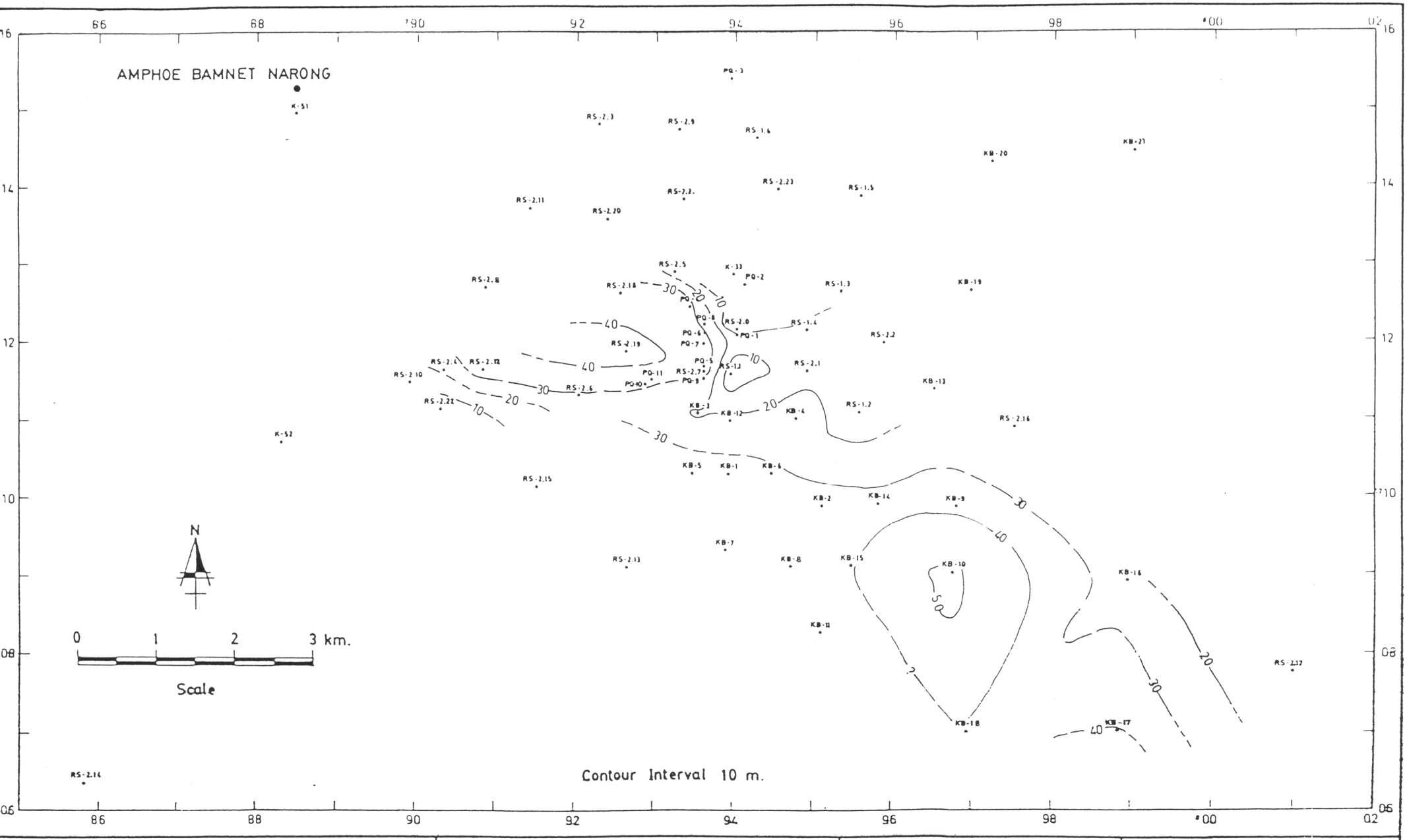
FIG. 2.2.2.1



ISOPACH MAP OF LOWER CLASTICS MEMBER

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FIG. 2.2.2.2

overlies the Lower Clastics Member and its thickness varies within the range of 12.51-125.59 meters. The depth to the top of the Member generally increases from the central part to the surrounding outer part, particularly southeastwardly, within the depth range of 150 meters above the mean sea level to 120 meters below the mean sea level (Figure 2.2.3.1). It is noted that the structure on top of this Member is mainly conformable with that of the underlying Lower Clastics Member and the complete sequences of Basal Salt Member. Besides, the thickness of the Member generally increases from the central part toward the surrounding outer part. The thickest zone in the southeastern part is thinning again eastwardly (Figure 2.2.3.2). The distribution of this Member is in the stratigraphic cross-sections (Plates 1 to 6).

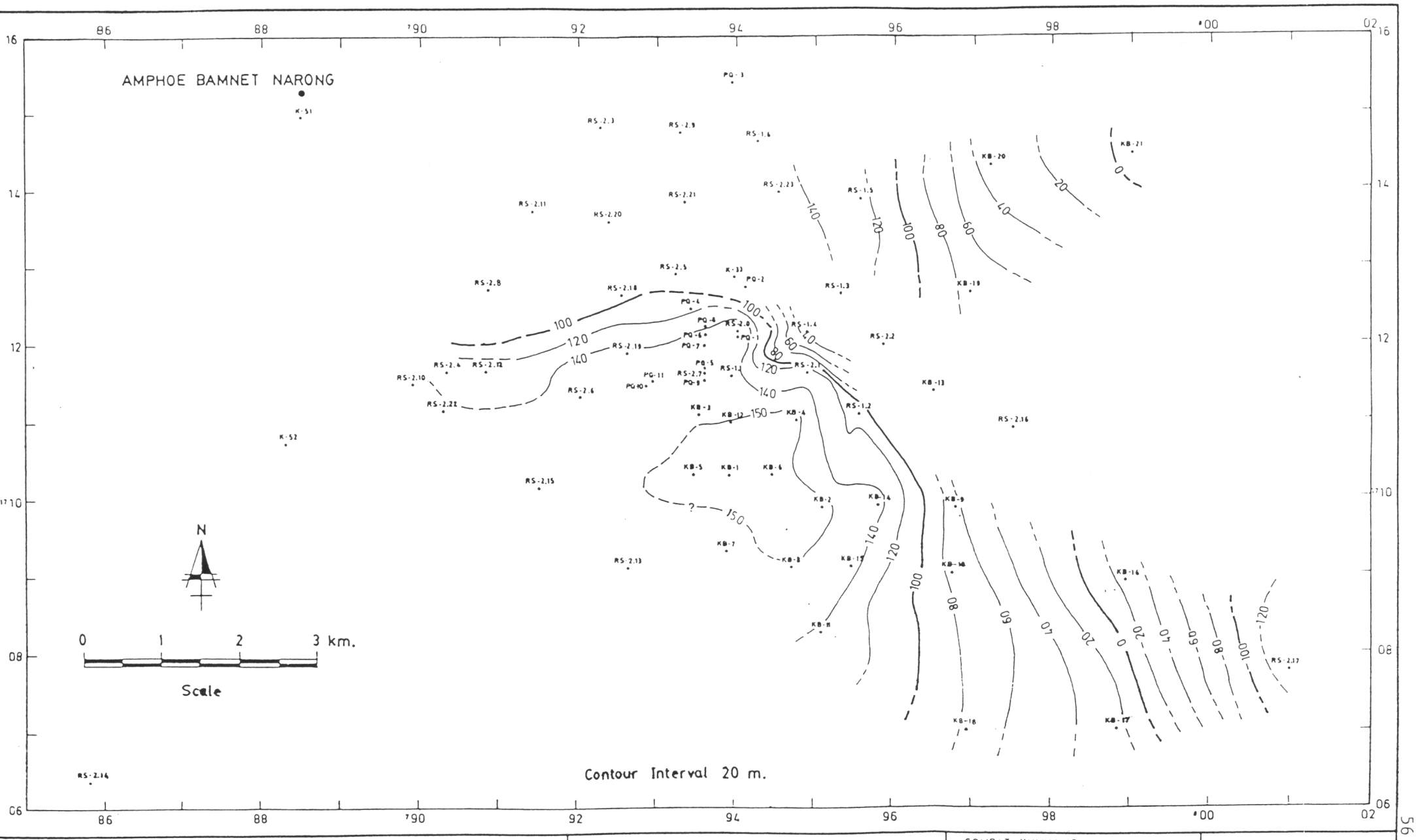
Generally, the Middle Salt Member has been divided into four Beds, namely, Lower Middle Halite, Middle Anhydrite, Upper Middle Halite, and Middle Cap Anhydrite, as described below :

a) Lower Middle Halite Bed

The thickness of the Lower Middle Halite Bed varies within the range of 10.94-22.17 meters. Generally, the Bed has nearly horizontal gradational contacts with the underlying Lower Clastics Member and with the overlying Middle Anhydrite Bed. The extension of the Bed is illustrated in the stratigraphic cross-sections (Plates 1 to 6).

b) Middle Anhydrite Bed

The Middle Anhydrite Bed is the typical key-bed of the Middle Salt Member. The Bed is very thin but uniformly present in the Middle Salt Member. The thickness of the Bed varies within the range of 0.11-2.04 meters but most commonly limited in the range of 0.60-1.00 meter.



STRUCTURAL CONTOUR MAP ON TOP OF MIDDLE SALT MEMBER

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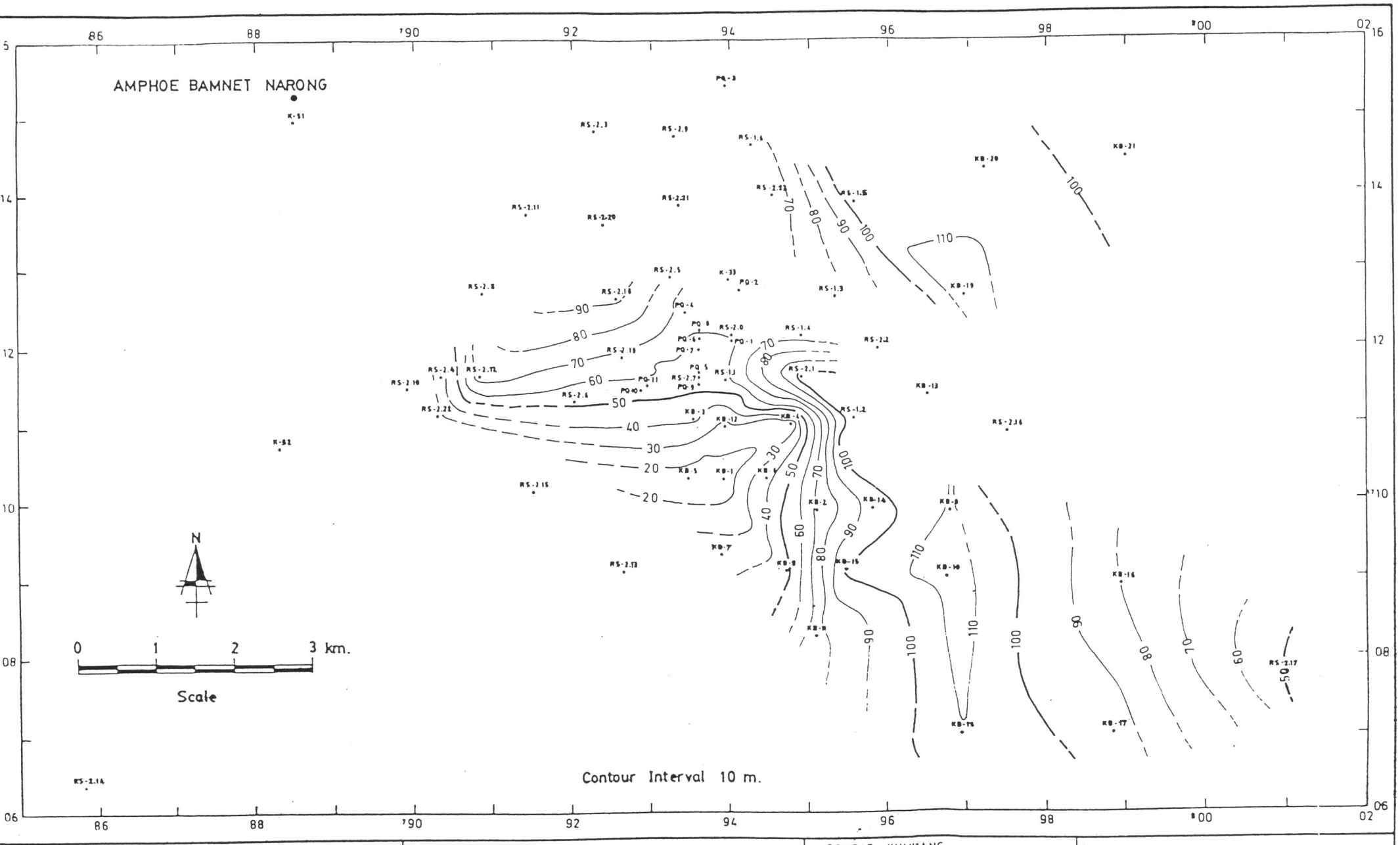
FIG. 2.2.3.1



ISOPACH MAP OF MIDDLE SALT MEMBER

On the Origin of Evaporite Deposits in the Maha-Sarakham Formation in Bamnet Narong Area Changwat Chaiyaphum

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FIG. 2.2.3.2

The bed has nearly horizontal gradational contacts with both the underlying Lower Middle Halite Bed and the overlying Upper Middle Halite Bed. The distribution of the Bed is presented in the stratigraphic cross-sections (Plates 1 to 6).

c) Upper Middle Halite Bed

The Upper Middle Halite Bed forms the major part of the Middle Salt Member. The thickness varies within the range of 1.46 to 95.33 meters. The Bed has nearly horizontal gradational contact with the overlying Middle Cap Anhydrite Bed. The extension of the bed is illustrated in the stratigraphic cross-sections (Plates 1 to 6).

d) Middle Cap Anhydrite Bed

The Middle Cap Anhydrite Bed is usually present in the uppermost part of the Middle Salt Member. The thickness varies within the range of 0-6.15 meters. Besides, the Bed is in nearly horizontal gradational contact with the overlying Middle Clastics Member.

2.2.4 Middle Clastics Member

The Middle Clastics Member generally overlines the Middle Salt Member with gradational contact. The thickness of the Member varies within the range of 8.94-53.00 meters. Besides, the contact with the overlying Upper Salt Member is a nearly horizontal gradational type. However, the Member is rather difficult to be seperated from the overlying Upper Clastics Member in some parts of the study area where the Upper Salt Member is absent. The distribution of this Member is illustrated in the stratigraphic cross-sections (Plates 1 to 6).

2.2.5 Upper Salt Member

The Upper Salt Member is only present in northeast and southeast parts of the study area where the overlying Upper Clastics Member of another different rock formation is very thick (Plates 2, 3 and 6). The thickness of the Member varies within the range of 0-51.30 meters. Besides, the contact with the overlying Upper Clastics Member is of nearly horizontal gradational type.

Generally, this Member has been divided into four Beds, notably, Lower Upper Halite, Upper Anhydrite, Upper Upper Halite, and Upper Cap Anhydrite, as described below :

a) Lower Upper Halite Bed

The Lower Upper Halite Bed is the lower part of the Upper Salt Member. The thickness varies from 0-13.08 meters. The contact with the overlying Upper Anhydrite is nearly horizontal gradational type.

b) Upper Anhydrite Bed

The thickness of the Upper Anhydrite Bed varies within the range of 0-1.05 meter. The contact with the overlying Upper Upper Halite Bed is nearly horizontal gradational type.

c) Upper Upper Halite Bed

The Upper Upper Halite Bed forms the major part of the Upper salt Member. The thickness varies within the range of 0-30.16 meters. Besides, the contact with the overlying Upper Cap Anhydrite Bed seems to be in the horizontal gradational (?) plane.

d) Upper Cap Anhydrite Bed

The thickness of the Upper Cap Anhydrite Bed varies within the range of 0-7.01 meters. It is noted that the Bed is rather thick if the underlying beds of Upper Salt Member are absent. In addition, the contact with that of the overlying Upper Clastics Member of another different rock formation is a nearly horizontal gradational type.

The distribution of these beds in Upper Salt Member is illustrated in the stratigraphic cross-sections (Plates 2, 3 and 6).

2.2.6 Upper Clastics Member

The Upper Clastics Member and the overlying Alluvium Member should be arranged under another different rock formation seperated from the underlying Maha Sarakham Formation of the Khorat Group because of their distinctive lithological features and considerable thickness. The thickness of the Upper Clastics Member varies within the range of 13.24 to 316.05 meters. This Member generally increases in thickness northeastwardly (Plates 2, 3 and 6). Besides, the contact with the overlying Alluvium Member is a nearly horizontal gradational type.

In the salt anticlinal areas, the Clastics Members, lies local unconformable (?) on the incomplete sequences of the Basal Salt Member, cannot be distinguished into Upper, Middle, or Lower Clastics Members (Figure 2.2.2, Plates 2, 3 and 6).

2.2.7 Alluvium Member

The Alluvium Member is the uppermost Member in the study area. The thickness varies within the range of 1.00-20.00 meters. It is interesting to note that this Member which overlies the Clastics Members

(Upper Clastics & Middle Clastics & Upper Clastics Members ?) in the incomplete sequences of the salt anticline areas is much thicker than the common Alluvium Member of the complete sequences (Figures 2.2.1 and 2.2.2). Above the incomplete sequences, the thickness of the Alluvium Member varies within the range of 3.05 up to 60.96 meters.

In the stratigraphic cross-sections of the study area (Plates 1 to 6), the Upper Clastics and the Alluvium Members are not seperated from each other.

Detailed mineralogy and petrography of the sequence in the study area is being discussed in the next chapter.