LATE JURASSIC VULCANICITY IN KARTABA-TANNOURINE DISTRICT OF CENTRAL LEBANON

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ABSTRACT

The late Jurassic volcanic rocks in Central North Lebanon have been studied in the Kartaba - Tannourine area. This area lies near the centre of the whole area, restricted to North Lebanon, which was affected by Late Jurassic vulcanicity.

The Late Jurasic volcanics consist of basalt lavas (often lateritised), ashes, tuffs and agglomerates (often calcareous) which form the bedded part of the volcanic complex together with intrusive basalts and vent tuffs and vent agglomerates. The lithology and petrography of the main rock-types have been described.

Three vent areas are recognised at Kartaba, Abboud, and Balaa, from contact relations of the rocks in the vents with the Kimmeridgian limestones and with the bedded part of the volcanic complex.

The volcanic history of the complex is summarised as

1. Phase of vulcanicity restricted to the Kartaba area and resulting in the eruption of lavas possibly from the subsidary Kartaba Vent.
2. Pyroclastic activity possibly connected with the main Kartaba vent.
3. Further phase of lava eruptions, possibly connected with the main Kartaba vent, and restricted to the Kartaba area.
4. Temporary cessation of volcanic activity and the deposition of a thin horizon of Kimmeridgian limestones.
5. Subsequent eruption of tuffs possibly from the Abboud vent.

6. Intrusion of basalts as sill below the upper horizon of Kimmeridgian limestones.

The presence of lateritised basalt lavas, associated with lignits and residual soil horizons, indicates that subaerial conditions Prevailed for a considerable time during the Late Jurasic volcanic activity.

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INTRODUCTORY REMARKS

The present thesis deals with some Late Jurassic volcanic rocks exposed in the Kartaba-Tannourine district of Central North Lebanon, some 45km to the northeast of Beirut. (platel). The rocks studied lie on the eastern margin of the main mass of Jurassic rocks which outcrop over a distance of 60km in a north-north-east direction from the latitude of Beirut in the core of the block uplift of the North Lebanon mountains. On a regional scale, the Late Jurassic vulcanicity was restricted to the Central North Lebanon, since these volcanic rocks die out to the south at the latitude of Jounie, and to the north at the latitude of Chekka (plate 2). It is possible that these volcanic rocks die out in an easterly and a westerly direction as well, since there are no Late Jurassic volcanics exposed in the Anti-lebanon where Jurassic rocks crop out in the Mount Hermon region, and since it appears that the volcanic rocks on the western margin of the Jurassic outcrop in North Central Lebanon are definitely thinner than those on the eastern margin. It is evident, from the distribution of the Portlandian (J_7) limestones of the uppermost Jurassic in the Lebanon, that the present distribution of the slightly older Late Jurassic volcanic rocks is an original feature and not a result of differential erosion connected with the possible unconformity between the Jurassic and the Cretaceous in Lebanon. Thus the present region of study lies near the centre of the Late Jurassic volcanic activity in the Lebanon. It is of interest that the Lower Cretaceous volcanics in the Lebanon show a rather similar distribution to those of Late Jurassic except in that the focus of activity is displaced to the north-northeast by some 30km.

The Late Jurassic volcanics in the Kartaba-Tannourine district consist of basalt lavas, bedded ashes, tuffs and agglomerates, and some interbedded sediments, together with intrusive basalts, and vent tuffs and agglomerates. Their complexity led Dubertret (1951) to refer to the Kartaba volcanic complex, and this term will be used in the present thesis. These rocks lying outside the units are referred to as the bedded parts of the volcanic complex.

The volcanic complex was mapped as basalts and tuffs on the separate sheets of 1:50000 scale geological map of Lebanon by Dubertret and others in 1943. Dubertret discussed vulcanicity in a general way without considering either the stratigraphy or the structure of the volcanic complex in any detail. However, he stated that the volcanics were erupted into a neritic environment in which wave action was effective, while the lignites associated with volcanic rocks accumulated in calmer water.

Renouard (1955) related vulcanism to orogeny and stressed that from the Sequenian Kimmeridgian times onward, this activity was subaerial and even continental in character.

Arkell (1956) discussed the Kimmeridgian limestones of the Lebanon, and stated that after the neritic phase of sedimentation, there followed in the Lebanon a volcanic episode, with eruption of this basalt flows and deposition of bedded ashes with bituminous shales and lignites. He probably considers that the volcanics were extruded either on land or in very shallow water.

The present study is based on detailed field mapping using several photographic copies (1:10000 scale) of the topographic maps (1:50000 scale) of Lebanon. The scale of these photographic maps was reduced to 1:20000 using a pantograph to prepare the map which illustrates this thesis (plate 3).

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GENERAL GEOLOGY AND GEOMORPHOLOGY OF THE AREA

The major stratigraphic units exposed in the area are as follows:

5. Aptian and Albian (C_2 to C_3) limestones, marls and shales.
4. Basal Cretaceous (C_1) Sandstones of (?) Neocomian age.
3. Portlandian (J_7) limestones of restricted occurrence.
2. The Late Jurassic volcanic complex which includes a 10m horizone of Kimmeridgian limestones towards the top.
1. Kimmeridgian (J_6) limestones.

The Late Jurassic volcanics are mainly exposed in the valleys of two major rivers which flow westwards across the area. These are the Nahr Ibrahim in the south, and the Nahr Al Jaouz further to the north. The volcanic rocks, which outside the vents dip gently to the east, crop out around the sides of these valleys at heights varying from 900m to 1800m above sea level. They are exposed by the head-waters and tributaries of the two main rivers, and on the intervening slopes. The volcanic rocks outside the vents overlie Jurassic limestones and dolomites of Kimmeridgian (J_6) age. The former are rather unfossiliferous, fine-grained, massive, poorly-bedded, grey limestones which show well-developed karstic weathering. The dolomites are coarser-grained, appear to have developed in the neighbourhood of faults and along veritcal joints in the limestones, and weather into dolomite sands. In addition, the limestones forming the vent margins are, in many places, strongly jointed, brecciated, calcite-veined, and dolomitised. The main rivers have cut deep steep-sided gorges into these Upper Jurassic rocks; the flat valley bottom of the Nahr Ibrahim is at a height of 800m above seal level, while the gorge of the Nahr Al Jaouz descends rather more rapidly along its course to a height of 1500m above sea level.

The slopes developed on the rocks of the volcanic complex on the other hand, are less steep so that the gorges open out at the sharp break of slope between the underlying limestones and dolomites, and the overlying volcanic rocks, to form sloping benches on the valley sides. The basalts which were not affected by pene-contemporaneous lateritisation, and some of the finer-grained but non-calcareous pyróclastic rocks, show well-developed spheroidal weathering related to the present land-surface. All stages can be observed from incipient alteration along joints, through the formation of spheroid of fresh rock surrounded by weathered material, to the complete disintegration of the original rock to form essentially unconsolidated rock-waste; this rock-waste is removed by soil-creep, and rain and rill action. Such weathered basalts can be distinquished from similarly weathered fine-grained and non-bedded pyroclasts by the presence of vesicles and amygdales, and the absence of clastic textures; however, both these features tend to be obscured in the more intense stages. A feature of this recent weathering which serves to distinguish it from the pene-contemporaneous lateritisation of basalt flows (described below) is that a clayey residuum is not formed. A further feature of interest is that basalt lava flows are more intensely weathered than intrusive basalts. This is interpreted as a consequence of the fact that the lava flows are generally interbedded with more porous and permeable pyroclasts which allow ground-water to percolate easily into joints in the lavas;

this would not be the case for the intrusive basalts which mainly form larger bodies of rock. The calcareous tuffs and the agglomerates weather somewhat differently into a thin veneer of rock-waste which is easily washed aways by rain and rill action. The lateritised basalts are more resistant to weathering, partly because they are impermeable, and partly because of their altered nature, and in many places form trap-features along the valley sides. As a consequence of all these effects the slopes developed on the volcanic rocks, except where tributaries of the two main rivers have cut down to the level of the Kimmeridgian limestones, are gentle and are covered by a mantle of rock-waste and soil which has been terraced for agriculture. These gentle slopes are only interrupted towards the top of the volcanic complex where a 10m thick horizon of normal Kimmeridgian limestone forms a well-developed escarpment which can be traced throughout much of the region.

Overlying the volcanic rocks are the Basal Cretaceous (C_1) Sandstones. These are well-bedded, medium-grained, cross-bedded, friable quartz sands which thin from 90m in the region of Kartaba northwards to 25-30m in the Tannourine district. Protected by the overlying Aptian (C_2) sediments which form a well-marked scarp feature, the Basal Sands are poorly exposed on rather steep hill-sides. There is, however, no marked break in slope between the Late Jurassic volcanic rocks and the overlying Basal Sandstones. The Aptian-Albian sediments are sandstones, argillaceous sandstones, oolitic and detrital limestones which show rudimentary cross-bedding, reef limestones, grey fine-grained limestones and greenish marls. The Aptian is divided in two by a 15m thick horizon of fine-grained massive limestone, known as the 'falaise de Blanche', which forms an escarpment throughout the region. The top of the Aptian is marked by the development of volcanic rocks, both basalt lavas and fine-grained pyroclastics. The Albian rocks pass upwards into the Cenomanian (C_4) which consists mainly of well-bedded, fine-grained, grey limestones and chalks, of considerable thickness.

The Late Jurassic volcanic rocks described above can be traced eastwards, along the north side of the Nahr Ibrahim valley and along the south-east side of the Nahr Al Jaouz valley until they are affected by a faulted flexure which trends NNE-SSW through Laklouk. This flexure, termed the Laklouk Flexure, forms the eastern margin to the Kartaba Horst in which Jurassic rocks dip gently westwards. (plate 4). These Jurassic rocks form a rugged mountainous area of karst topography in which the highest points are Jebel Firhe (1640m), Jebel Tartij (1815m) and Jebel Jaj (1954m). In the steep zone of the Laklouk Flexure, rocks varying in age from Kimmeridgian (J_6) to Aptian (C_2) dip eastwards at angles which in several places approach the vertical. These steeply dipping rocks crop out along the floor of a valley, which runs NNE from just east of Kartaba, through Laklouk, to Belaa. This valley joins those of the two main rivers, but its floor is much higher than either of the main valleys so that at its southern and northern ends it drops rapidly towards the Nahr Ibrahim and the Nahr Al Jaouz, respectively. This valley through Laklouk has a steep western wall formed by the Jurassic rocks of the Kartaba Horst, but opens out to the east since the escarpment formed by the Aptian 'falaise de Blanche' is lower. The late Jurassic volcanic rocks are exposed along the valley, but in several places are cut out by the faulting connected with the Laklouk Flexure. This faulting also obscures the stratigraphic relations between the volcanic rocks where these are exposed.

The area which is limited by the escarpment of the 'falaise de Blanche', and which lies east of the valley through Laklouk between the two main valleys of the Nahr Ibrahim and the Nahr Al Jaouz, is low hilly country in which sediments and volcanic rocks of Upper Aptian to Albian age are exposed. This area lies at the foot of the steep escarpment of Cenomanian (C_4) limestones. This escarpment, which limits the high mountainous plateau lying immediately to the west of the major fault and flexure zone on the western side of the Belaa valley, curves round the southern side of the Nahr Ibrahim valley and then trend northwards until it reaches the southern side of the valley of the Nahr Al Jaouz where it regains its original northeast trend.

In addition to the three more-or-less continuous areas of volcanic rocks described above, there are three smaller areas which are surrounded entirely by Kimmeridgian (J_6) limestones. These areas are found at Boutraiche, Jebel Firhre and Deir Houb.

STRUCTURE OF THE AREA

As will be already clear from the previous section the most important structure developed in the area is the Laklouk Flexure (plate 4). The steeply dipping rocks associated with this flexure form a monoclinal zone between the gently westerly dipping rocks of the Kartaba Horst to the west and the gently easterly dipping rocks to the east. Since the Kimmeridgian (J_6) limestones immediately below the volcanic complex at Kartaba on the flat eastern limb of this monocline are at a height of 1100m, and since the summits at heights of over 1900m within the Kartaba Horst are Kimmeridgian limestones which are stratigraphically below the rocks of the volcanic complex, it is clear that the Kartaba Horst has been uplifted by at least 800m relative to the rocks to the east beyond the Laklouk Flexure.

A number of faults cut the rocks of the area. Firstly, there is a fault zone trending parallel to the Laklouk Flexure which, although dis-continuous, cuts out part of the sequence including the Late Jurassic volcanics within the steep zone. A continuation of this fault-zone to the south appears to be responsible for the faulting-in of the volcanic complex outlier at Boutraiche between two subsidary faults of the fault-zone. Secondly, there are several faults which trend from east-west to ENE-WSW across the area. Two such faults are seen in the south of the area. The course of the Nahr Ibrahim below Kartaba is controlled by the more northerly of these two faults, while the other lies 1km to the south. whereas the southerly fault has a similar down-throw but to the north.

A small outlier of tuffs is exposed adjacent to the northerly fault on its southern side. Two more faults with ENE-WSW trends are seen in the northern part of the area and can be considered a single fault zone since they merge in the area of Deir Houb. Both extend for more than 10km, and together cut across the main Jurassic inlier of the North Lebanon. On the western side of this inlier the Jebel Firhre Fault downthrows westerly dipping rocks to the north, whereas on the eastern side of this inlier the Deir Houb Fault downthrows easterly dipping rocks to the south. The fault zone is therefore either a hinge fault of normal character or, more likely, a wrench fault with a dextral displacement of over 1km. The volcanic outliers of both Jebel Firhre and Deir Houb are associated with these faults and, since neither contains volcanic rocks which are clearly extrusive, both areas could be vents rather than faulted-in outliers of extrusive rocks.

LITHOLOGY AND PETROGRAPHY OF THE VOLCANIC ROCKS

The main lithologies of the volcanic complex are as follows:

a). Basalts and Laterised Basalts..

b). Tuffs and Agglomerates.

c). Calcareous Tuffs.

d). Lignites and Residual Soil Horizons.

The basalts found within the volcanic complex are both intrusive and extrusive. The intrusive basalts, as mentioned above, are less altered by recent weathering than the extrusive basalts, the finer-grained and less vesicular examples of both intrusive and extrusive basalts tend to be less altered than coarser-grained and vesicular rocks.

The basalts are fine-grained to medium-grained rocks, with the elongated plagioclase laths having a maximum length of 1.5mm. The majority of the basalts, both intrusive and extrusive, are non-porphyritic, both macroscopically and microscopically. Porphyritic basalts with macrophenocrysts of greenish yellow olivine, are however, developed as lavas in the lower levels of the volcanic complex. Both the intrusive and extrusive basalts are generally non-vesicular in nature, except that sparse elongated amygdales, containing mainly calcite and chlorite, and up to 1cm in length, are found in a thin layer towards the base of the flows, and as an even thinner layer towards the top. These elongated amygdales tend to be generally parallel to the upper and lower margins of the flows, but in some cases they are inclined at oblique angles to the margins.

In thin section the fine-grained and non-porphyritic basalts have

TABLE No. I

The maximum extinction angle of albite twins and the extinction angles of combined Carlsbad-albite twins normal to (010) for the plagioclase felspars.

Slide No.	Max. extinction angle on albite twins	Combined extinction angles on Carlsbad-albite twins	Relief	Optical sign
1	32 An 58	15 30 An 55	Fairly low	+
2	35 An 66	19, 25 An 52	low	+
3	26 An 48	16 25 An 48	low	+
4	29 An 52	22 26 An 56	Fairly low	+
5	34 An 60	16 28 An 54	low	+
6	28 An 48	17 25 An 50	low	+
7	33 An 59	18, 30 An 58	Fairly low	+

intergranular textures. The plagioclase laths tend to have random orientations; granules of augite and less abundant olivine occupy the spaces between the plagioclases. Elongate and skeletal crystals of ilmenite are more common than magnetite granules. The matrix of the porphyritic basalts is similar, but micro-and macro-phenocrysts of olivine are abundant. The medium-grained basalts do not have intergranular textures; instead subophitic textures are developed between augite and plagioclase. Olivine is not abundant in these rocks.

The plagioclase in both the fine-grained and medium-grained basalts has a composition ranging from An 48 to An 66 with sodic Labradorite as the most common type. This is determined from

a) Maximum extinction angles on well-developed albite twins.

b) Combined extinction angles on Albite-Carlsbad twins.

c) Relief and optical sign.

The determinations are listed in Table I, for the several rocks sectioned. The augite has a purplish colour which indicates a titan-augite composition. These features indicate that the basalts are alkaline olivine-basalts.

Alteration is pronounced in many of the basalts; olivine is partly or totally altered to iddingsite along fractures; augite is chloritised; plagioclase is sericitised and kaolinised.

Several of the basalt lava flows have been affected by lateritisation. Since the intensity of the changes decreases from the tops of individual flows downwards towards their bases, it is evident that this lateritisation is pene-contemporaneous with the vulcanicity. Typically the uppermost part of the lateritised basalt flow are altered to a compact, structure-less, yellowish-green rock with a greasy lustre. The original igneous textures are completely destroyed during these changes, and the original nature of the rock can only be inferred from the fact that such laterised basalts grade downwards into less altered material showing some relict structures, and from general field relations. The main part of the laterised flows is deep maroon in colour, and such rocks have been referred to as 'chocolate-coloured shales', (Dubertret, 1951). Calcite amygdales are preserved in these rocks but, otherwise, the basalt has been totally altered to a compact and structure-less rock. The contact between upper and lower rock-types is highly complex, with veins, stringers and blebs of pale-coloured rock developed within the main mass of the maroon rock.. In some flows this maroon rock grades downwards into heavily altered basalt. Individual flows of such lateritised basalts can be traced for considerable distances throughout the area.

It is evident that these lateritised basalts were developed subaerially under conditions of intense tropical weathering during long periods of volcanic inactivity. This inference is confirmed by the association of such lateritised basalts with overlying beds of lignite and residual soils, clearly developed under subaerial conditions, during periods of non-deposition.

The pyroclastic rocks vary in grain-size from ashes to agglomerates. Pyroclasts developed within the sequences outside the vents are usually bedded tuffs, whereas those in the vents are generally unbedded agglomerates, although there are many exceptions to this general statement. Further, the fine-grained tuffs include rocks, here called calcareous tuffs, in which calcareous material is well-developed in the matrix. In the agglomerates. On the other hand, there are often abundant blocks of fine-grained limestones clearly derived from the underlying Jurassic limestones.

Very fine-grained ashes are only occasionally developed within the volcanic complex. They are finely bedded, rather calcareous greyish-green, rocks in which small fragments of basalt are occasionally found. The laminations in the ashes are less than 1cm in thickness, and are caused by grain-size differences. These ashes grade into calcareous tuffs with an increase in grain-size.

The calcareous tuffs are well-bedded rocks in which the laminations, up to 5cms in thickness, are due to variations in the amount of basalt fragments relative to the calcareous matrix, and to variations in the size of the basalt fragments. In thin section, the rock consists of rather ragged basalt fragments, which are entirely altered to a greenish isotropic material (possibly chloropheite), set in a fine-grained matrix of calcareous material. This calcareous material contains a few fragments of limestone which shows occasional crystals of calcite set in a very fine grained and largely irresolvable calcite matrix. The basalt fragments are generally less than 1mm in length, whereas those of limestone are up to 2mm in diameter.

These calcareous tuffs grade with increasing grain-size into agglomerates containing rounded blocks of limestone, and with decreasing content of calcareous matrix into normal tuffs. It is therefore evident that the calcareous tuffs themselves are a product of pyroclastic activity, and are formed by the intense comminution of limestone fragments derived from the underlying Jurassic limestones during vent formation.

The normal tuffs are well-developed in the area, both within the vents and within the volcanic sequence outside the vents. In the vents, the normal tuffs are rather coarse-grained and include occasional large blocks (up to 1m diameter) of limestone or basalt. Within the sequence outside the vents the tuffs are finer-grained and do not contain so many or so large limestone or basalt blocks as the vent tuffs. Generally the normal tuffs are rather massive rocks which do not show marked bedding due to grain-size or compositional differences on a small scale. However, some of the tuffs within the vents are bedded on a larger scale with beds up to 5m thick developed by variations in the relative abundance of limestone and basalt fragments. Commonly, as in the Kartaba vent, limestone blocks and smaller fragments are concentrated towards the base of each bed, while basalt fragments and larger blocks become more abundant towards the top. The tuffs outside the vents are rather poorly bedded or completely unbedded, at least within the limits of the exposures. Towards the top of the volcanic complex, and above the upper horizon of Kimmeridgian limestone, the tuffs show a gradual decrease in grain-size towards the contact with the Basal Cretaceous Sandstones, only interrupted by slight variations in grain-size and composition which results in beds some 10-50cm thick.

In thin section, the original features of the tuffs have been obscured by alteration. Fragments of altered basalt can be identified, and these are set in a fine-grained to irresolvable matrix which contains lathshaped plagioclase crystals.

The normal tuffs grade into agglomerates by an increase in the abundance of basalt and limestone blocks, and by an increase in the grain-size of the matrix in which the blocks lie. Limestone blocks up to 2m in diameter are common; the larger of these tend to be sub-angular but the smaller are generally sub-rounded. These limestone blocks consist of grey fine-grained limestone which is lithologically identical to the underlying Kimmeridgian limestones, from which they have clearly been derived. The basalt blocks show similar variations in size and shape as the limestone blocks. The basalt blocks show a rather wide range in lithology, with amygdaloidal types well-represented. Many basalt blocks show planar structures, formed by the parallel orientation of elongate amygdales. Moreover, no basalt blocks have the forms of volcanic bombs, so that it appears that the basalt blocks were derived through the brecciation of already solidified lava within the volcanic went by explosive activity.

In addition to the blocks of limestone found within the agglomerates, there are also larger masses of limestone, up to 15m in maximum dimension, enclosed in the agglomerates. The interiors of these masses are lithologically identical to the Kimmeridgian limestones but towards their margins the rock becomes increasingly brecciated. This brecciated limestone contains occasional irregular fragments of basalt, together with more abundant fragments of limestone. These fragments are isolated by "net-veins" of smaller limestone fragments cemented together with calcite.

Very occasionally these brecciated masses of limestone are associated in the field with large blocks of quartzite. This quartzite consists of sub-rounded grains of quartz cemented by a fine-grained calcite matrix.

Both the masses of brecciated limestone and the less common blocks of quartzite are found in agglomerates which lie within vents. These vent agglomerates are unbedded, and often merge with the surrounding tuffs. However, agglomerates are also developed outside the vents within the volcanic sequence. These are in many places well-bedded due to variations in the sizes of the blocks within the agglomerate.

THE VENTS

Several vents have been recognised in the Kartaba-Tannourine area during the present study (plate 5). Two main criteria for recognising vents have been used in the field:

1). Contact relations with the Kimmeridgian limestones.

2). Interruption of stratigraphic horizones within the volcanic complex.

In the first case, the contact between the Kimmeridgian limestones and the bedded portion of the volcanic complex is generally conformable on a large scale; there is no evidence that there is any major unconformity developed below the volcanic rocks of the volcanic complex. Apart from those volcanic rocks exposed in the steep zone of the Laklouk Flexure. the conformable junction between the Kimmeridgian limestones and the bedded parts of the volcanic complex is either flat-lying or gently dipping. Thus, where this is not the case, the contact relations can generally be interpreted as a steep contact between the Kimmeridgian limestones and volcanic rocks lying within a vent which penetrates the limestones. This evidence is confirmed, in some cases, by clear indications that the limestones adjacent to the vent margins have been affected by the formation of the vents. In no case was it reasonable to interprete the contact relations as due to faulting.

In the second case, both the upper horizon of Kimmeridgian limestones developed within the upper part of the volcanic complex, and the lava flows (particularly those affected by lateritisation) within the bedded parts of the volcanic complex, afford stratigraphic horizons which can be traced for considerable distances. Thus, where these are cut out, it is generally reasonable to infer a contact between the bedded parts of the volcanic complex and volcanic rocks lying within a vent. Again, there is no evidence that such contacts are a result of faulting.

The vents recognised penetrate both the Kimmeridgian limestones and the bedded parts of the volcanic complex in its lower levels. There is, however, no definite evidence that the vents are related to the Late Jurassic, rather than the Early Cretaceous (Aptian-Albian), vulcanicity. Indeed, the blocks of quartzite which are present in the vent agglomerates could indicate that these vents are in fact Early Cretaceous in age. However, the sporadic occurrence of these quartzite blocks, and the lack of clear evidence that they are altered Basal Cretaceous Sandstones rather than sandstone blocks either brought up from below or formed from sandstones laid down locally during the Late Jurassic volcanic activity, both mitigate against the vents being other than Late Jurassic in age.

Three main vent areas, other than those possibly developed in association with the cross-faults at Jebel Firhre and Deir Houb, have been recognised as follows:

a). A complex vent at Kartaba, formed by the coalescence of two vents.

b). A single vent at Abboud.

c). A single vent at Belaa.

The composite vent of Kartaba is well-exposed on the slopes below the village. The main vent lies to the north of the subsidary vent. The main vent consists of unbedded agglomerates containing large masses of brecciated limestones concentrated and indeed marking the vent margins. In places minor intrusions of basalt penetrate the agglomerates. The vent is intruded into Kimmeridgian limestones on its northern and south-eastern sides, and these limestones in the latter area are very heavily dolomitised and veined with coarse-grained calcite for at least 50m from the near-vertical contact. On the northeastern margin, the vent agglomerates cut across basalt lavas, some flows of which are lateritised, and tuffs. Overlying these lavas and tuffs in the bedded part of the complex are coarse tuffs and bedded agglomerates, and it is entirely possible that these were formed in connection with the formation of the main Kartaba vent, especially so bacause they dip away from the vent area at angles up to 30°. The eastern and southern margins of the main Kartaba vent are formed by bedded tuffs and agglomerates lying within the subsidary Kartaba vent, which is, therefore, the earlier of the two. The contacts of this subsidary vent are less well exposed than those of the main Kartaba vent, but in places appear to have rather low attitudes. However, field relations between the vent tuffs and agglomerates and the Kimmeridgian limestones on the eastern, southern and western sides of this vent are sufficient to confirm that the former rocks do lie within a vent, since they are developed well below the uppermost horizon of the main mass of Kimmeridgian limestones, and since the bedding in these limestones in the walls of the vent is cut across by the vent margins. The tuffs and agglomerates in this subsidary Kartaba vent show bedding on a large scale dipping towards the central parts of the vent away from the vent margins. It is not certain if this is an original feature or whether later subsidence or movements connected with the main vent have affected these rocks.

The Abboud vent is locally well exposed on the valley sides of the two streams which join below Abboud and then flow south to the Nahr Ibrahim. The actual vent margin is only exposed on the southern side of this vent. There the course of the more easterly tributary follows the vent margin until the confluence of the two tributaries, beyond which the vent margin trends obliquely uphill to the southeast, cutting across flows of lateritised basalts and tuffs. In places, the vent margin is marked by small masses of brecciated limestone. Moreover, traced up the valley of the more easterly tributary the vent margin cuts across the horizon of Kimmeridgian limestone found within the volcanic complex. In this area, poorly bedded tuffs with rather occasional blocks of limestone and basalt occur within the vent. The bedding is generally flat lying. Sporadic exposures of similar tuffs are found on the hill-slopes above the Kartaba-Afka road, and their limits probably serve to define the margins of the Abboud vent. On the easterly side of the valley below Abboud a sill of massive, medium-grained, basalt can be traced south from the vent margin below the upper horizon of Kimmeridgian limestones. At a point approximately 1km from the vent this sill cuts across the limestone horizone and appears to intrude the overlying tuffs as a thick tongne. Where it has broken through the limestone, the basalt show auto-brecciation with angular blocks of massive to amygdaloidal basalt surrounded by highly amygdaloidal basalt which locally merges into drusy patches of coarse-grained calcite. In addition large blocks of limestone have been carried upwards and form inclusions up to 5m long in the auto-brecciated basalt. These limestone masses are heavily brecciated and carry fragments of limestone and basalt in a recrystallised calcite matrix.

The tuffs lying within the abboud vent are limited on the western side of the Abboud vent by an area of massive, medium-grained, basalt. This basalt can be traced westwards to Kartaba where it appears to underlie, and intrude, the upper horizon of Kimmeridgian limestone. Further, this limestone horizon does not extend to the margin of the abbound vent but appears to be cut out in some way by this intrusive basalt. However, the exact relations between these two rocks are obscure for lack of adequate exposures in the field.

The Belaa vent in the Tannourine area is not well exposed except locally. However, the contact relations of rocks considered to lie in the vent and the Kimmeridgian limestones to the outside clearly indicate the presence of a vent there. The contact relations between the rocks within the vent and the volcanic rocks within the bedded part of the complex are obscured by the lack of adequate exposures; moreover, most of the stratigraphic horizons, either limestone or volcanic, appear to crop out beyond the vent margins. The bulk of the rocks lying within the vent are agglomerates which in some places are well-bedded. Large masses of brecciated limestone are found associated with these agglomerates. However, there are also adjacent areas of massive, medium-grained, basalt which could be intrusions associated with the vent. Field relations are inadequate to determine whether or not this is so. Further, a tongue of unbedded agglomerate extends northeastwards from the area of the vent agglomerates, but appears to lie at the base of the bedded part of the volcanic complex. Again, it is likely that these rocks are associated with the vent, but the exact relations are not clear for lack of adequate field exposures.

Of the three areas of volcanic rocks lying entirely within the Jurassic rocks and associated with faults, that of Boutraiche near Kartaba appears to be an infaulted part of the bedded volcanic complex, particularly so because it includes horizons of lateritised basalts. However, neither of the other two areas, at Jebel Firhre and at Deir Houb, contains lateritised basalts or other rocks clearly part of the bedded volcanic complex, Instead, they consist of unbedded tuffs and basalts; it is possible that these areas represent small vents, located on the Jebel Firhre - Deir Houb wrench fault zone.

STRATIGRAPHY AND TIME RELATIONS OF THE VOLCANIC COMPLEX

Within the bedded part of the volcanic complex, the upper horizon of Kimmeridgian limestone forms a well-marked stratigraphic unit. Above this horizon, only variable thicknesses of poorly bedded tuffs, becoming finer-grained towards their upper contact with the Basal Cretaceous Sandstones are found throughout the area. From the contact relations, described in the last section, between the rocks within the Abboud vent and the upper horizon of Kimmeridgian limestone it is possible that this uppermost horizon of bedded tuffs is associated with the Abboud vent; otherwise, this vent must be post-Jurassic in age. This tentative conclusion is supported by the fact that this horizon of bedded tuffs reaches a maximum thickness of some 30m in the Abboud area and thins to 10m at Rhabate and Saraita to the south of the Nahr Ibrahim, and to 5m to the north at Tannourine. Further, these tuffs are coarsest in the Abboud area, and become finer-grained to the south, west and north. Moreover, the pyroclasts in the Abboud vent are fine-grained agglomerates and coarse tuffs so that it is unlikely that the explosive activity of this vent was great.

Below the upper horizon of Kimmeridgian limestone, there is a considerable thickness (up to 60m) of massive, medium-grained, basalt, which extends throughout most of the Kartaba area. In several localities this basalt shows instrusive relations with the overlying limestone as at Kartaba and at Abboud, (plates 6 and 7) and this interpretation is supported by its general lack of extrusive structures and textures and by its lack of pene-contemporaneous alteration. Moreover, it would appear from field relations that this intrusive basalt sheet is associated with the Abboud vent in its earlier stages of formation. It is therefore suggested that this basalt was intruded as a near-surface sheet below the upper horizon of Kimmeridgian limestone, prior to the eruption of the Abboud vent. The upper horizon of Kimmeridgian limestone must have been well-lithified for this to occur. Subsequently, the pyroclastic activity of the Abboud vent developed with the eruption of bedded tuffs which overlie the limestone horizon. However, it appears that the intrusive basalt remained unsolidified so that it later intruded the limestone horizon and overlying tuffs, probably during this phase of eruption.

This intrusive basalt does not extend into the Laklouk area, but in the Tannourine area there is a mass of massive, medium-grained, basalt which occupies a similar position below the upper horizon of Kimmeridgian limestones and which reaches a thickness of 100m (plate 8). Although there is no adequate field evidence, it appears from its general lithological character to be intrusive in a similar manner to the Kartaba mass.

The rocks underlying the upper horizon of Kimmeridgian limestone, other than the intrusive masses of basalt described immediately above, show considerable variations in lithology and thickness. They thicken from 20 - 35m in the Tannourine area, and from 30 - 40m south of the Nahr Ibrahim, to a maximum of 130 - 150m in the Kartaba-Abboud area. This increase in thickness is also marked by an increase in the lithological diversity of the bedded parts of the volcanic complex. A horizon of pyroclastic rocks developed in the Kartaba area serves to divide these rocks into two parts. This horizon can be traced from the area to the west of Kartaba, where well-bedded calcareous tuffs immediately overlie the main Kimmeridgian limestones, eastwards through Kartaba and Abboud, where it overlies basalts and lateritised basalts which wedge out both to the west and to the east, and then southwards to Rhabate and Saraita, where it overlies a thin horizon of lateritised basalts lying immediately above the Kimmeridgian limestones. This horizon of calcareous tuffs merges in the same easterly direction into coarser-grained pyroclastic rocks in the neighbourhood of Kartaba and Abboud where well-bedded agglomerates with limestone and basalt blocks are found at this horizon. To the east of abboud, these agglomerates give way to well-bedded normal tuffs. It would thus appear that this horizon of pyroclastic rocks which nowhere reaches more than 20m in thickness is associated with the main Kartaba vent. Above this pyroclastic horizon in the Kartaba-Abboud area are basalts and lateritised basalts, which in places are associated with lignites and residual soil horizons. Reaching a thickness of some 30m in the area mentioned this volcanic horizon wedges out to the east and thins to the west. It is possible that these rocks were erupted from the main Kartaba vent. Below this pyroclastic horizon in the Kartaba-Abboud district lie basalts and laterites with a maximum thickness of 110m. These volcanic rocks wedge out rapidly to the east where the pyroclastic horizon comes to lie directly upon Kimmeridgian limestones, and thin to the east to form a thin horizon of lateritised basalts lying on the Kimmeridgian limestones in the area of Rhabate and Saraita (plate 9). Thus, it is possible that this lower volcanic horizon is associated with the early subsidary vent at Kartaba.

In the Tannourine district, the rocks underlying the intrusive mass of basalt are lateritised basalts underlain by tuffs, which themselves immediately overlie the main Kimmeridgian limestones. The stratigraphic relations of these rocks with those of the Kartaba area are uncertain. It is possible that the horizon of tuffs in the former area is equivalent to the pyroclastic horizon in the latter area. However, it is equally likely that these pyroclasts in the Tannourine area are related to the Belaa vent.

CONCLUSIONS

From the foregoing discussion, the following conclusions are made:

1) The late Jurassic Vulcanicity is restricted to the Central North Lebanon. The main exposures of the Late Jurassic volcanics are exposed in a NNE-SSW direction along the western and eastern margins of the J 6 mass cropping out a distance of 60 km, in a north-north-east direction from the Latitude of Beirut in the core of the block uplift of the North-Lebanon mountains. The Kartaba-Tannourinne district lies in the centre of this region and the volcanic rocks appear to thin and eventually disappear in all directions.

2) The volcanic activity took place during Late Kimmeridgian times since the bulk of the Late Jurassic volcanic rocks are developed stratigraphically above the main mass of J 6 limestones but below a thin upper horizon of the same rocks. It is assumed that towards the end of the Kimmeridgian, limestone deposition gave way to volcanic activity which probably lasted for a considerable time before the resumption of the short sedimentary phase which gave rise to the upper horizon of the J 6 limestones. Subsequently, a short limited phase of volcanic activity occured before the deposition of the Basal Cretaceous Sandstones.

3) The volcanic activity was centered around three major vents at Kartaba, Abboud, and Balaa. Further vents are possibly developed as outliers of volcanic rocks in the north and the south of the area.

The main vents recognized penetrate both the Kimmeridgian limestones and the bedded parts of the volcanic complex in its lower levels. In no case, was it reasonable to interprete the contact relations as due to faulting. However, the outliers in the north and the south are strongly related to subsidiary cross-faults, which are probably wrench-faults.

4) The bulk of the Late Jurassic volcanics consists of tuffs and lateritised basalts. The lateritisation is indicative of penecontempraneous weathering in a subaerial environment, and is associated with the development of lignites and residual soil horizons. The presence of the upper horizon of Kimmeridgian Limestones within the bedded part of the volcanic complex indicates, however, the marine conditions were developed during part of the volcanic episode, and suggests that the subaerial conditions were probably xxxx a result of volcanic eruptions building up the volcanic piles to above sea-level than the result of the overall shallowing of the Late Jurassic sea at the time of the main volcanic episode due to relative uplift. However, the sporadic occurrence of Portlandian (J 7) oolitic reef and limestones at the top of the upper horizon of the Kimmeridgian Limestones, and the gradational contacts of the upper volcanic horizons with the Basal Cretaceous Sandstones, indicate a gradual shallowing of the Late Jurassic sea following the main volcanic episode but, again, this could be due to sedimentation rather than to relative uplift. Evidence of a Jurassic-Cretaceous unconformity is lacking, within the region studied.

APPENDICES

STRATIGRAPHIC SECTIONS

LATE JURASSIC VULCANICITY IN KARTABA-TANNOURINE AREA

NO. I.

Boutraiche Locality

Detailed Description To Accompany Plate 7

Total Thickness 68m

Interval Number	Rock Unit	Thickness	Description
Bottom			
1	Calcareous Tuff	5m	Pale yellowish, medium to fine-grained, hard, thin-bedded,Fractured, occasional staining along fracture planes.
2	Ash	3m	Greyish Green, medium to fine-Grained, thin bedded, interbedded with thin laminations of calcareous tuffs.
3	Basalt	12m	Black greyish, medium-grained, excessively weathered, amygdaloidal, occasional calcite veins either concentric or planar in nature, elogated. amygdales filled with chlorite and calcite throughout.
4	Lalerite	9m	Pale yellowish with common hematite staining, friable occasionally sticky leached tops.
5	Basalt	23m	Black, fine-grained, massive, fresh, non-vesicular.
6	Tuff	16m	Grey, medium grained, friable, unbedded, occasional basalt fragments towards the base.

APPENDIX No. II

W. Kartaba Locality

Detailed Description To Accompany Plate 7

Total Thickness 55m

Interval Number	Rock Unit	Thickness	Description
Bottom			
1	Calcareous Tuff	7m	Pale yellowish, medium to fine-grained, thin-bedded, fractured.
2	Ash	1m	Grey greenish, medium to fine-grained, thin bedded, interbedded with thin laminations of calcareous tuffs.
3	Basalt	5m	Black greyish, medium grained, excessively weathered, amygdaloidal, occasional calcite veins, elongated amygdales filled with calcite.
4	Laterite	4m	Pale yellowish with common hematite stains, friable occasionally sticky.
5	Basalt	21m	Black, fine-grained, massive, fresh, nonvesicular.
6	J 6 Limestone	6m	Greyish, fine-grained massive, non-fossiliferous.
7	Tuff	11m	Grey, Grading up wards into light Grey, medium grained, friable, unbedded.

APPENDIX No. III

Kartaba Locality

Detailed Description to Accompany Plate 7

Total Thickness 172m

Interval Number	Rock Unit	Thickness	Description
Bottom 1	Laterite	6m	Dark maroon, medium-grained, friable, residual masses of basalt.
2	Basalt	28m	Black-greyish, medium-grained, massive, cut by calcite veins, amygdaloidal.
3	Laterite	11m	Marooh to pale yellowish, very fine grained, friable, occasionally cut by calcite veins, residual masses of basalt fragments throughout.
4	Basalt	26m	Black-greyish, medium-grained weathered, amygdaloidal, cut by calcite veins amygdales filled with chlorite and calcite, Pillow lava like structures formed by concentric calcite veins.
5	Calcareous Tuff	20m	Pale yellowish, medium-grained, hard, well bedded, fractured, stained along fracture planes.
6	Basalt	13m	Black greyish, medium grained, extremely weathered, amygdaloidal, Interbedded with tuff laminations and calcite, amygdales filled with calcite and chlorite.
7	Marl	1m	Yellow brownish, coarse-grained, semifriable, earthy, un-bedded.
8	Lignite	1m	Greyish black earthy and mucky occurs in thin seams.
9	Shale	1m	Yellow brownish, fine-grained, sticky, earthy, slightly bedded.
10	Laterite	8m	Pale yellowish, friable, residual masses of basalt throughout.

Interval Number	Rock Unit	Thickness	Description
11	Basalt	37m	Black, medium grained, hard, fresh, nonvesicular.
12	J 6 Limestone	6m	Greyish, crystalline, poorly bedded, massive, un-fossiliferous.
13	Tuff	14m	Dark grey grading to light grey upwards, medium grained to finer upwards, occasional basalt fragments near the bottom, becoming tuffaceous sands near the top.

APPENDIX No. IV

Abboud Locality

Detailed Description to Accompany Plate 7

Total Thickness 202m

Interval Number	Rock Unit	Thickness	Description
Bottom 1	Laterite	14m	Dark maroon, very fine-grained, friable, occasionally interbedded with lenticular calcite veins.
2	Basalt	29m	Black-greyish, medium grained, weathered, interbedded with calcite veins.
3	Laterite	16m	Pale yellow to maroon, very fine-grained, residual masses of basalt leached tops.
4	Basalt	41.5m	Black greyish, medium grained excessively weathered, cut by calcite veins, amygdaloidal.
5	Calcareous Tuff	13m	Yellow greyish, coarse to medium-grained, interbedded with thin laminations of tuff, poorly bedded.
6	Basalt	16.5m	Grey blackish, medium-grained, amygdales filled with chlorite and calcite, interbedded with thin laminations of tuffs, excessively weathered.
7	Laterite	16m	Pale yellowish with occasional hematite stains, small residual masses of basalt slightly sticky.
8	Basalt	56m	Black, fine grained, hard, fresh, nonvesicular.

APPENDIX No. V

South Abboud Locality

Detailed Description To Accompany Plate 7

Total Thickness 116m

Interval Number	Rock Unit	Thickness	Description
Bottom 1	Basalt	27m	Black greyish, medium-grained, with calcite veining showing concentric and planar types, weathered.
2	Laterite	13m	Maroon to pale yellowish, very fine grained, residual masses of basalt towards base.
3	Tuff	19m	Grey, coarse-grained to medium un-bedded, associated with thin beds of calcareous tuffs, Fragments of vesicular basalts.
4	Laterite	10.5m	Pale yellowish, with occasional iron stains, very fine Grained,
5	Basalt	28.5m	Black greyish, medium grained weathered, amygdales of chlorite and calcite, interbedded with tuffs.
6	J 6 Limestones	9m	Greyish, fine-grained poorly bedded, massive, unfossiliferous.
7	Tuff	28m	Grey blackish to light grey upwards, semiconsolidated, medium grained to finer upwards, becoming tuffaceous sands toward the top.

APPENDIX No. VI

Balaa Locality

Detailed description To Accompany Plate 8

Total Thickness 134m

Interval Number	Rock Unit	Thickness	Description
Bottom 1	Tuff	19m	Greyish black, coarse grained, cut by calcite veins, occaisional basalt fragments near the bottom, un bedded.
2	Lalerite	16m	Pale yellowish to light maroon, very fine-grained, sticky near the bottom.
3	Basalt	88m	Blacky fine-grained, massive fresh, non vesicular.
4	J 6 Limeston	6m	Greyish, fine-grained massive, thick bedded, un-fossiliferous.
5	Tuff	5m	Grey blackish grading upwards to light grey, coarse-grained, unbedded, friable, becoming tuffaceous sands near the top.

APPENDIX No. VII

Bsaboua Locality

Detailed Description To Accompany Plate 8

Total Thickness 84m

Interval Number	Rock Unit	Thickness	Description
Bottom 1	Tuff	11m	Greyish black, medium-grained, friable, unbedded, basalt fragments throughout.
2	Laterite	7m	Pale yellowish to maroon, very fine-grained, sticky, semi consolidated.
3	Basalt	54m	Black, fine-grained, massive, hard, fresh, nonvesicular.
4	J 6 Limestone	7m	Greyish, fine-grained massive, thick-bedded, un-fossiliferous.
5	Tuff	5m	Grey blackish to light grey upwards, coarse-grained grading to fine upwards, embedded basalt fragments towards the bottom, becoming tuffaceous sands near the top.

APPENDIX No. VIII

Tannourine Locality

Detailed Description to Accompany Plate 8

Total Thickness 62m

Interval Number	Rock Unit	Thickness	Description
Bottom 1	Tuff	9m	Greyish black, medium-grained, friable, unbedded, basalt fragments towards the bottom, occasionally interbedded with calcite veins.
2	Laterite	8m	Light maroon, fine-grained, friable, earthy downwards.
3	Basalt	37m	Black greyish, fine-grained, massive, hard, fresh, nonvesicular.
4	J 6 Limestone	5m	Greyish, crystalline, compact, massive, thick-bedded.
5	Tuff	3m	Grey blackish to light grey upwards, coarse grained to finer upwards, un bedded, basalt fragments towards base.

APPENDIX No. IX

Rhabate Locality

Detailed Description To Accompany Plate 9

Total Thickness 61m

Interval Number	Rock Unit	Thickness	Description
Bottom 1	Laterite	11m	Maroon to yellowish grey upwards, very fine-grained, friable.
2	Tuff	29m	Black to grey, coarse-grained, slightly bedded, occasionally cut by calcite, veins basalt fragments throughout.
3	J 6 Limestone	12m	Greyish, crystalline hard, compact, poorly-bedded, unfossiliferous.
4	Tuff	9m	Black greyish to light grey upwards, coarse to fine-grained upwards, becoming tuffaceous sands near the top.

APPENDIX No. X

Saraita Locality

Detailed Description To Accompany Plate 9

Total Thickness 45m

Interval Number	Rock Unit	Thickness	Description
Bottom 1	Laterite	7m	Maroon to yellow greyish upwards, fine-grained, friable, semi-consolidated downwards.
2	Tuff	21m	Black greyish, coarse-grained, semi-consolidated, poorly-bedded, occasionally cut by calcite veins, basalt fragments towards base.
3	J 6 Limestone	10m	Greyish, very fine-grained, hard, compact, massive, poorly-bedded, unfossiliferous.
4	Tuff	7m	Greyish black to light grey upwards, coarse to fine-grained upwards, becoming tuffaceous sands near the top.

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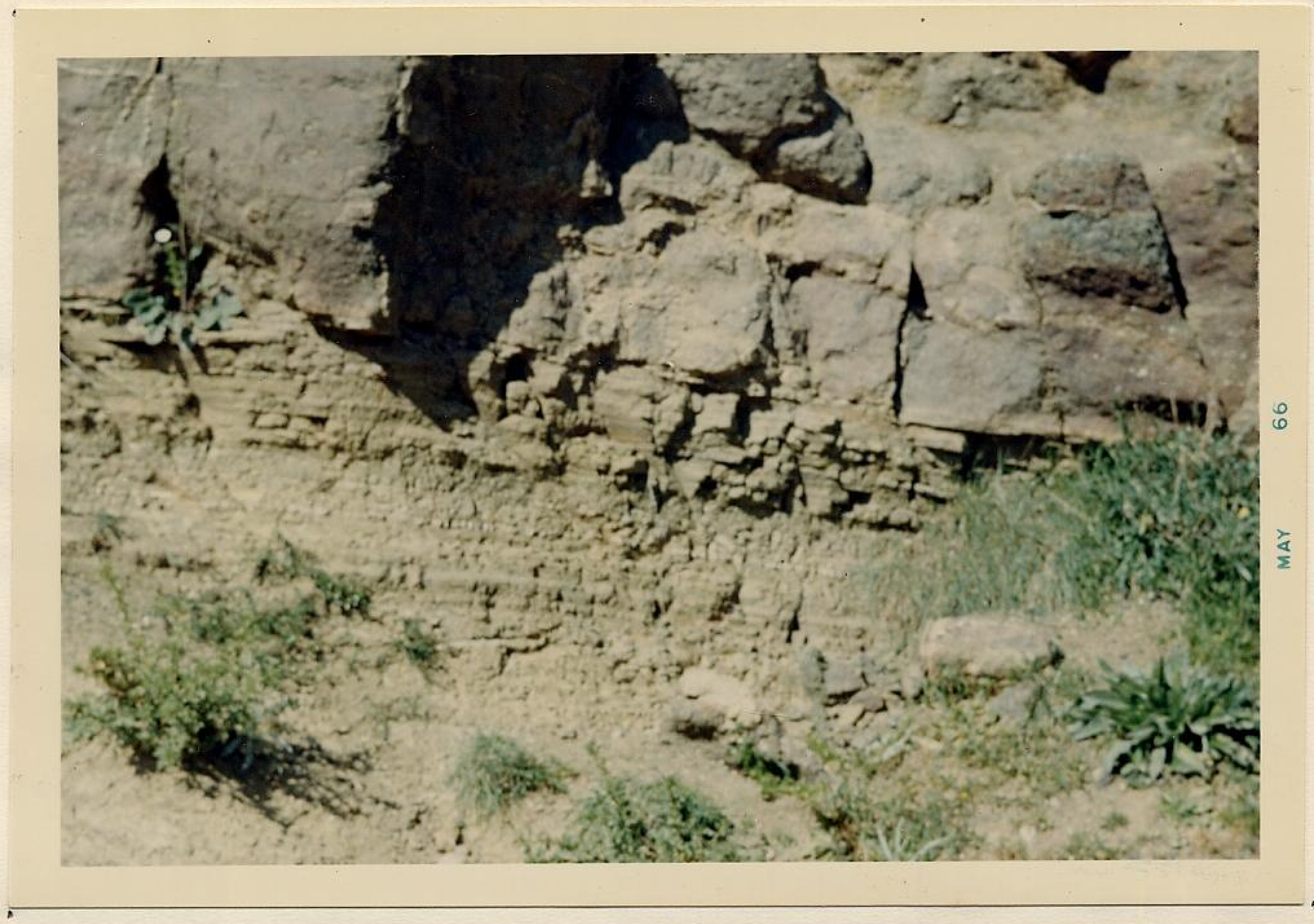


Photograph I; Kartaba locality; Thin-bedded calcareous tuffs.

Photograph 2; Kartaba locality; Intrusive basalt in the vent.

Photograph 3; Abboud locality; Bedded tuffs with embedded basalt fragments in the vent.

Photograph 4; Belàa locality; Lava with calcite gashes.

Photograph 5; Belaa locality; Lenticular flint horizon in tuffs.

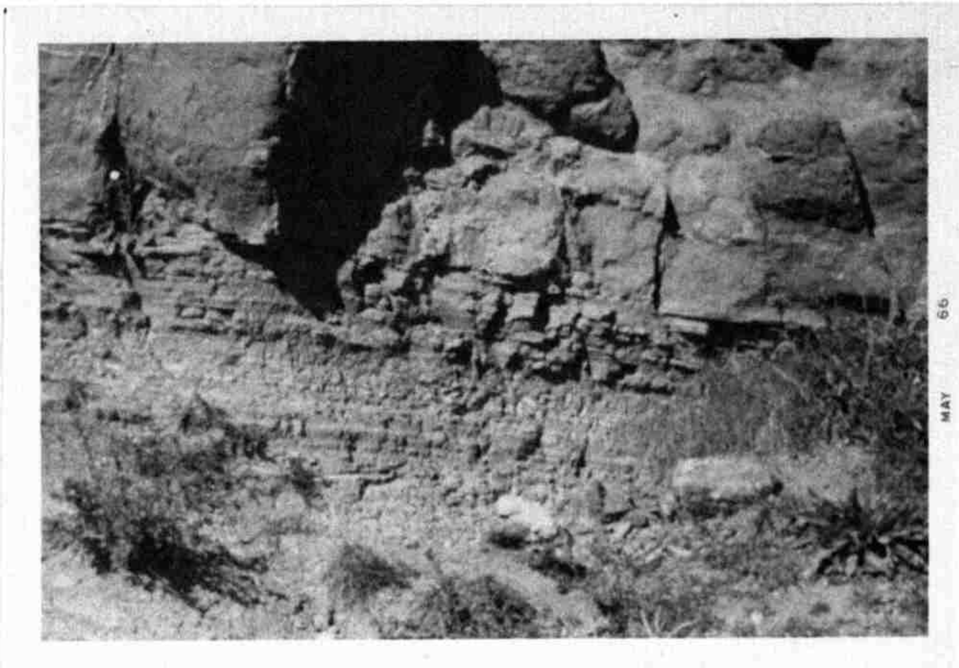
Photograph 6; Houdiene locality; Lateritised basalt.

Photograph 7; Rhabate-Saraita; The upper horizon of J 6 limestone.

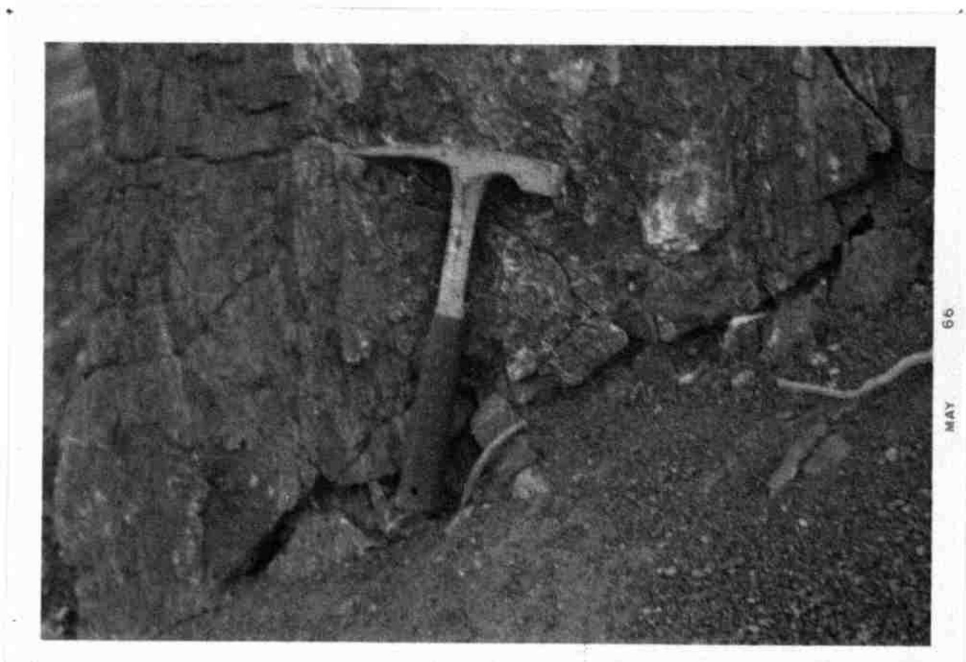
Photograph 8; Tannourine; Differential weathering in basalt.

Photograph; 9; Abboud; Auto - Brecciated lava.

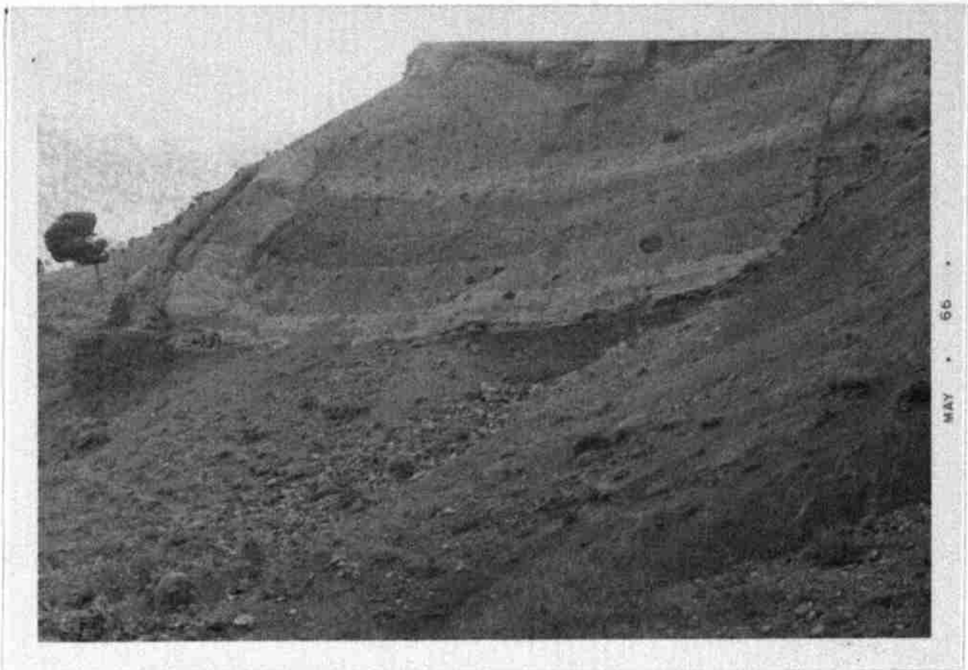
Photograph 10; Houdiene; Minor flow folding in Lava.



Photograph I; Kartaba locality; Thin-bedded calcareous tuffs.

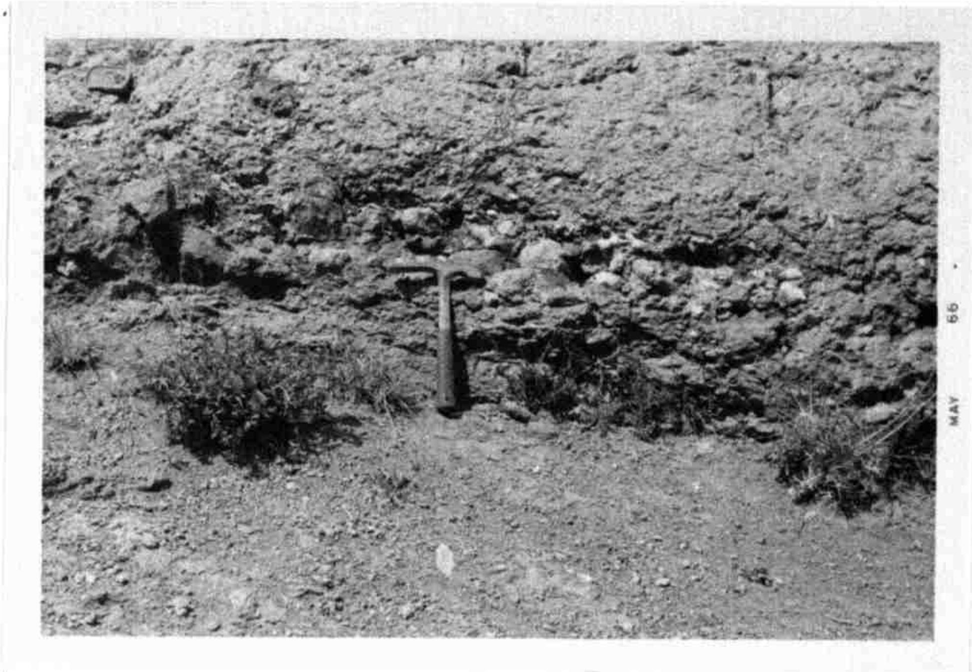


Photograph 2; Kartaba locality; Intrusive basalt in the vent.



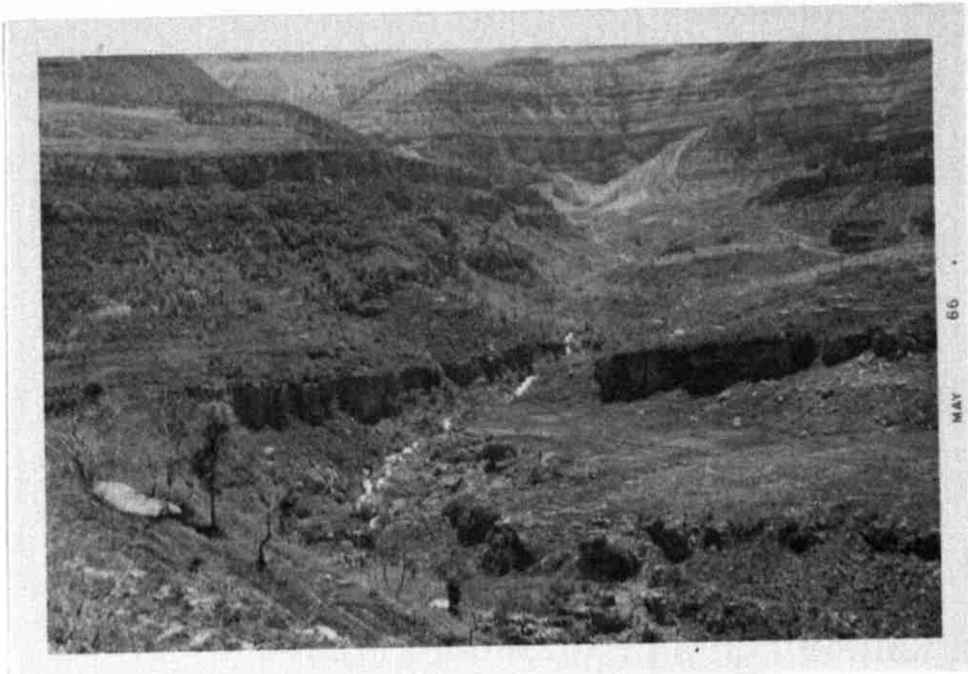
Photograph 3; Abboud locality; Bedded tuffs with embedded basalt fragments in the vent.

Photograph 4; Belâa locality; Lava with calcite gashes.



Photograph 5; Belaa locality; Lenticular flint horizon in tuffs.

Photograph 6; Houdiene locality; Lateritised basalt.



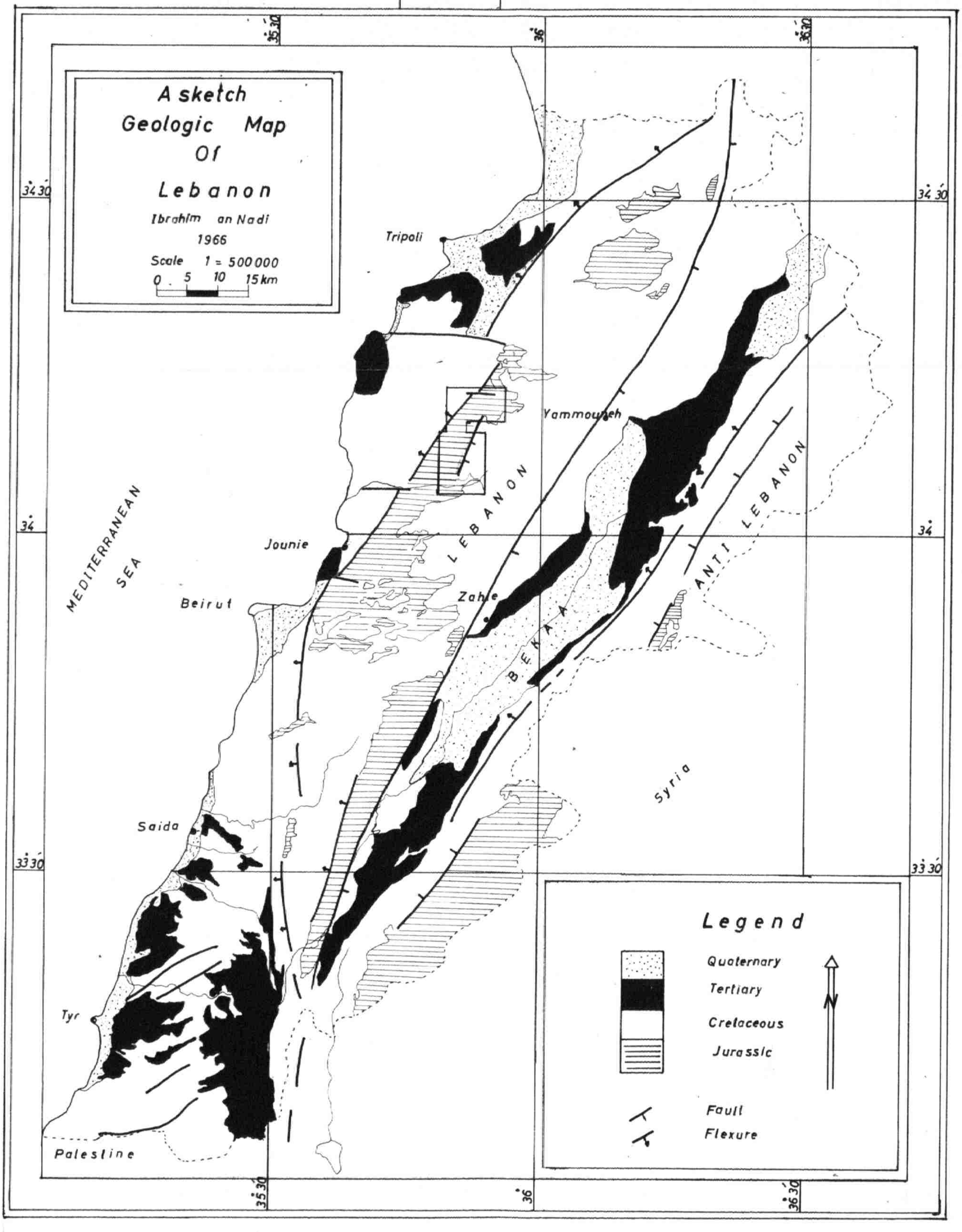
Photograph 7; Rhabate-Saraita; The upper horizon of J 6 limestone.

Photograph 8; Tannourine; Differential weathering in basalt.

Photograph; 9; Abboud; Auto - Brecciated lava.

Photograph 10; Houdiene; Minor flow folding in Lava.

PLATE 1

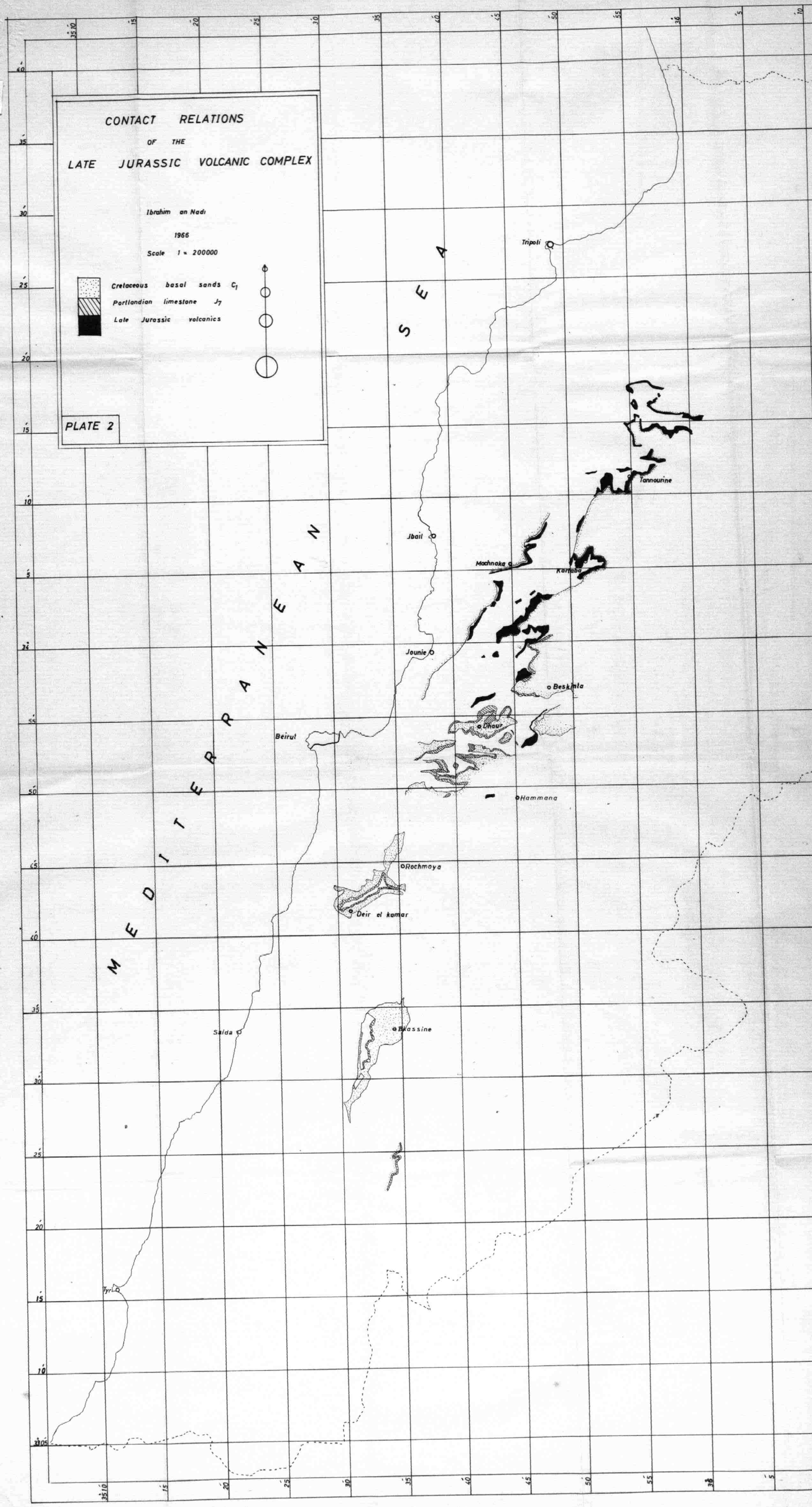


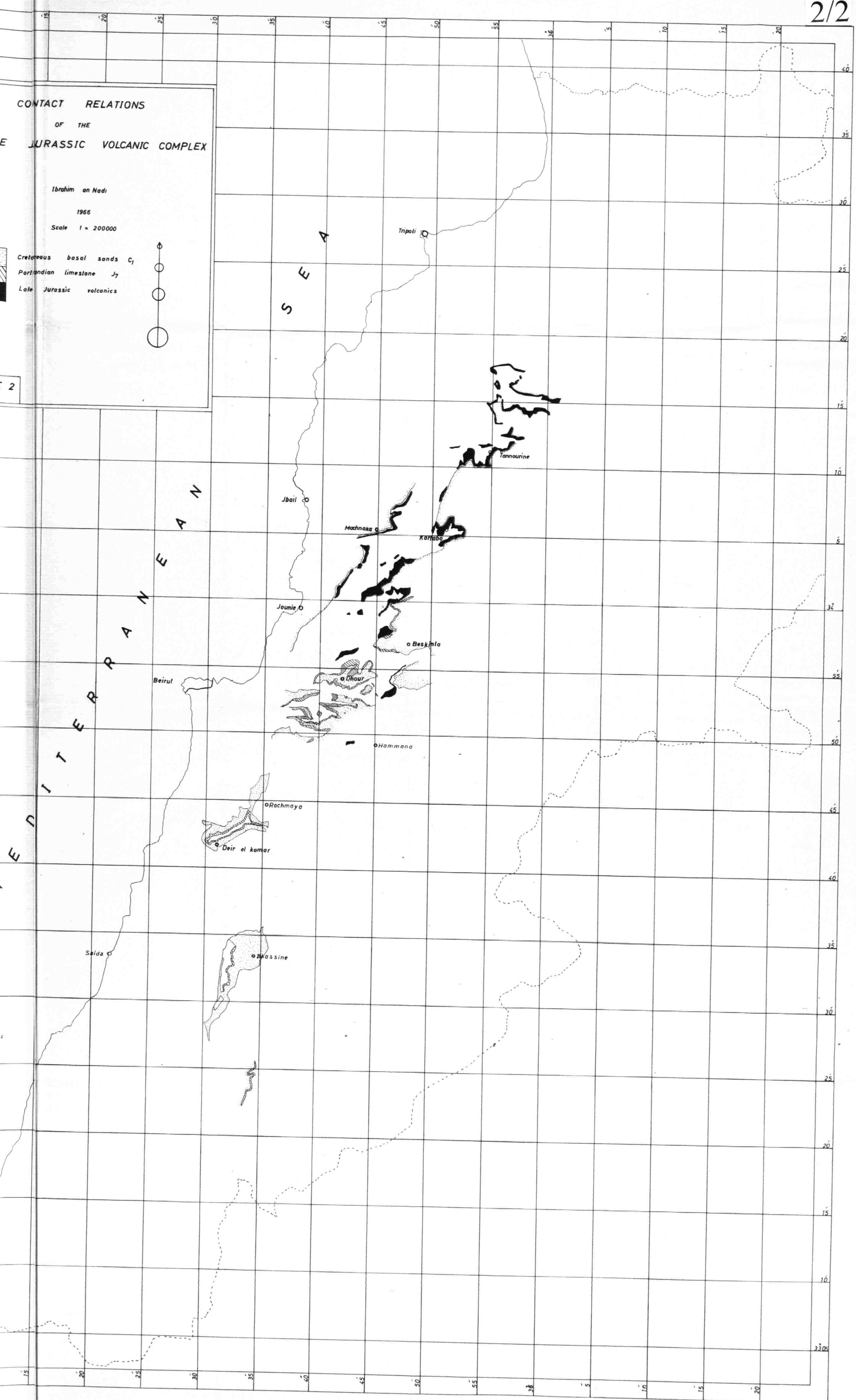
A sketch Geologic Map Of Lebanon
Ibrahim an Nadi
1966
Scale 1 = 500 000
0 5 10 15 km
35 30
36
36 30
34 30
34
33 30
Tripoli
Yammouneh
Jounie
Beirut
Zahle
Saida
Tyr
Palestine
MEDITERRANEAN SEA
LEBANON
BEKAA
ANTI LEBANON
Syria
Legend
Quaternary
Tertiary
Cretaceous
Jurassic
Fault
Flexure

1/2

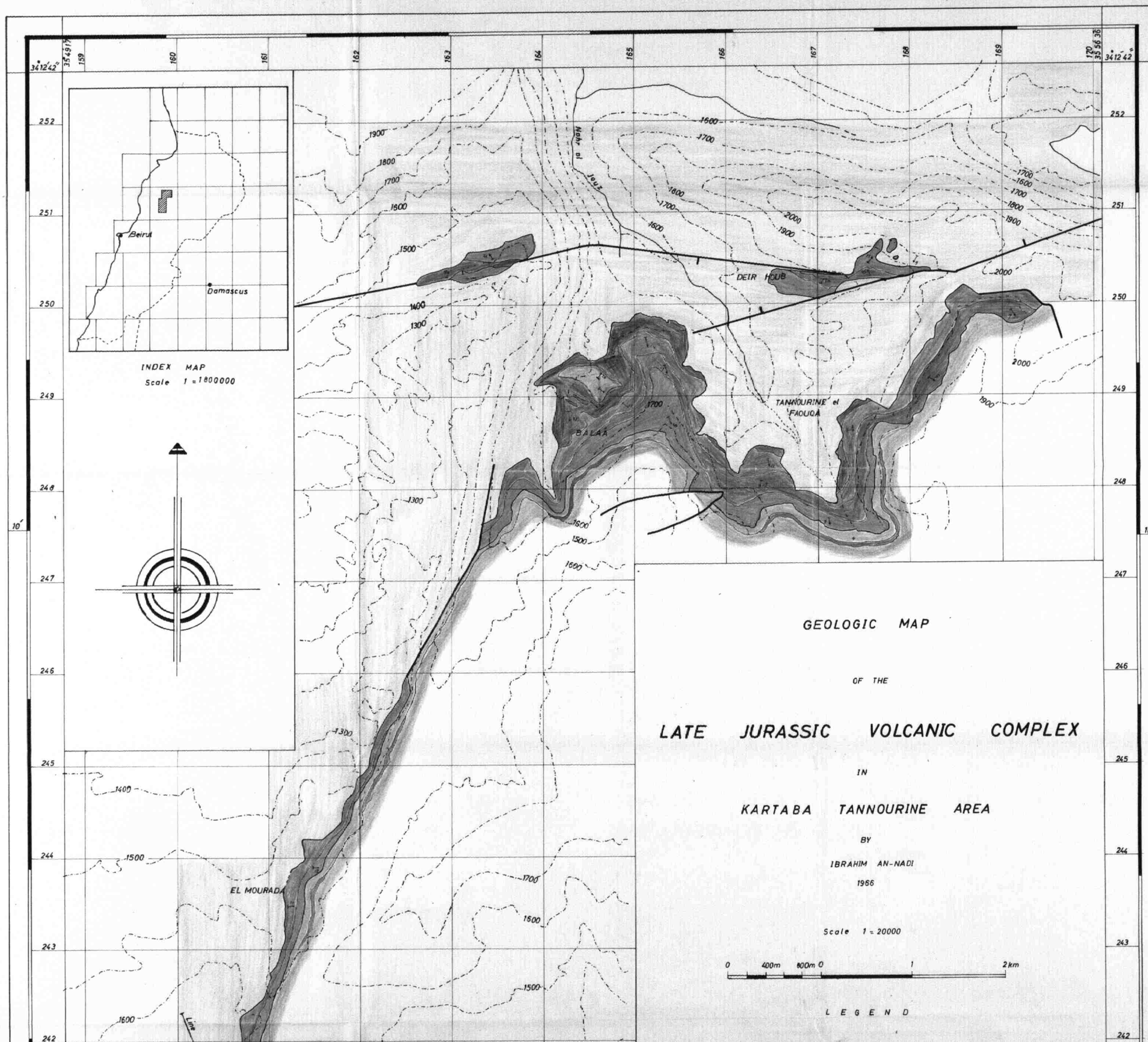

CONTACT RELATIONS
OF THE
LATE JURASSIC VOLCANIC COMPLEX
Ibrahim an Nadi
1966
Scale 1 = 200000
Cretaceous basal sands C_1
Portlandian limestone J_7
Late Jurassic volcanics
PLATE 2
MEDITERRANEAN SEA
Tripoli
Tannourine
Jbail
Machnaka
Kartaba
Jounie
Beskinta
Beirut
Dhour
Hammana
Rochmaya
Deir el kamar
Saida
Bkassine
Tyr

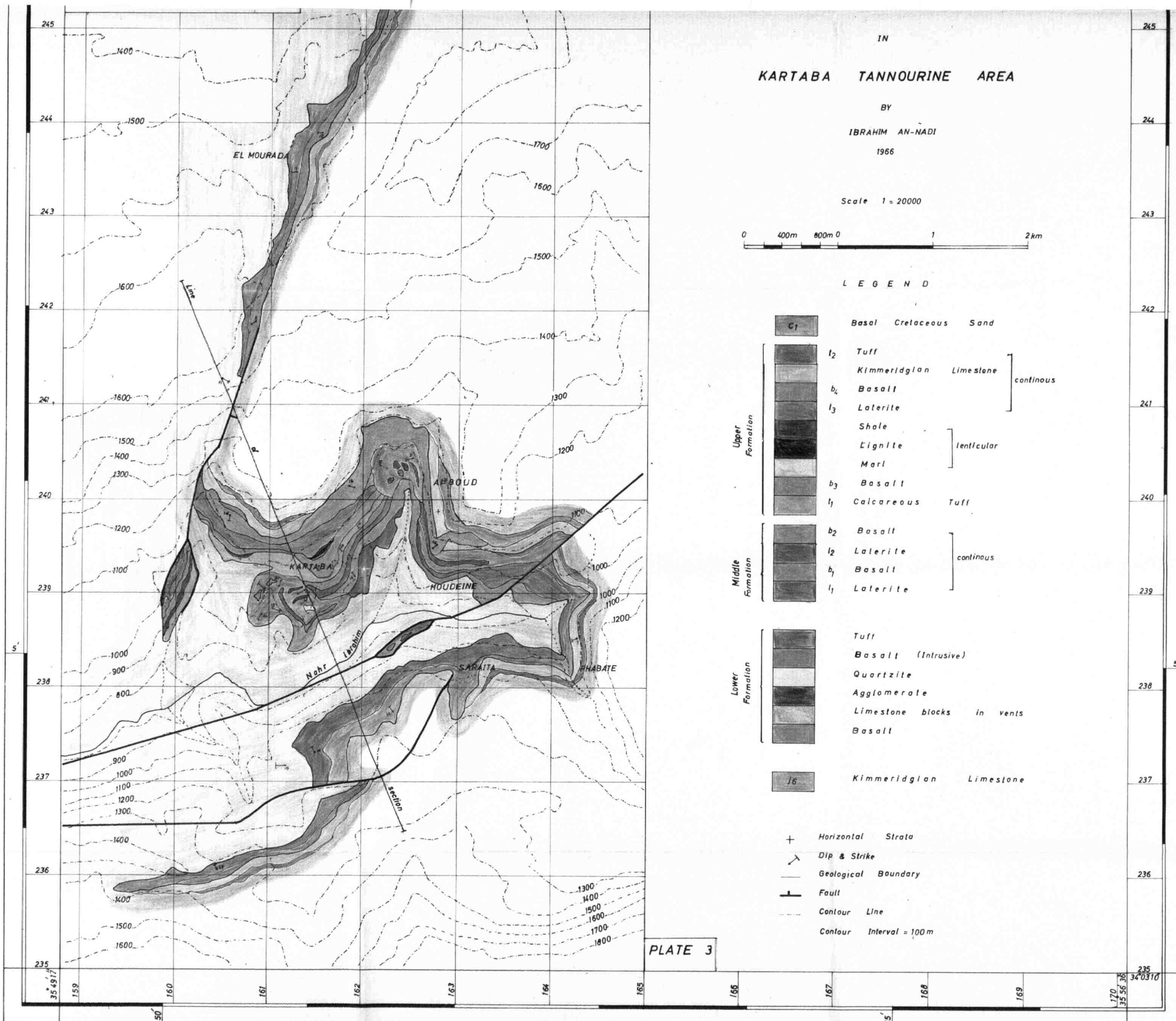
1/2


CONTACT RELATIONS
OF THE
LATE JURASSIC VOLCANIC COMPLEX
Ibrahim an Nadi
1966
Scale 1 = 200000
Cretaceous basal sands C1
Portlandian limestone J7
Late Jurassic volcanics
PLATE 2
MEDITERRANEAN SEA
Tripoli
Tannourine
Jbail
Machnaka
Kartaba
Jounie
Beskinta
Beirut
Dhour
Hammana
Rochmaya
Deir el kamar
Saida
Bkassine
Tyr


CONTACT RELATIONS
OF THE
E JURASSIC VOLCANIC COMPLEX
Ibrahim an Nadi
1966
Scale 1 = 200000
Cretaceous basal sands C1
Portlandian limestone J7
Late Jurassic volcanics
T 2
MEDITERRANEAN SEA
Tripoli
Tannourine
Jbail
Machnaka
Kartaba
Jounie
Beskinta
Beirut
Dhour
Hammana
Rachmaya
Deir el kamar
Saida
Bkassine

1/2


GEOLOGIC MAP
OF THE
LATE JURASSIC VOLCANIC COMPLEX
IN
KARTABA TANNOURINE AREA
BY
IBRAHIM AN-NADI
1966
Scale 1 = 20000
0 400m 800m 0 1 2km
LEGEND
INDEX MAP
Scale 1 = 1800000
Beirut
Damascus
Nahr el Jouz
DEIR HOUB
BALAA
TANNOURINE el FAOUQA
EL MOURADA
Line


IN
KARTABA TANNOURINE AREA
BY
IBRAHIM AN-NADI
1966
Scale 1 = 20000
0 400m 800m 0 1 2km
LEGEND
C1 Basal Cretaceous Sand
Upper Formation
t2 Tuff
Kimmeridgian Limestone
b4 Basalt
l3 Laterite
continous
Shale
Lignite
Marl
lenticular
b3 Basalt
t1 Calcareous Tuff
Middle Formation
b2 Basalt
l2 Laterite
b1 Basalt
l1 Laterite
continous
Lower Formation
Tuff
Basalt (Intrusive)
Quartzite
Agglomerate
Limestone blocks in vents
Basalt
J6 Kimmeridgian Limestone
Horizontal Strata
Dip & Strike
Geological Boundary
Fault
Contour Line
Contour Interval = 100m
PLATE 3
EL MOURADA
ABBOUD
KARTABA
HOUDEINE
SARAITA
RHABATE
Nahr Ibrahim
Line section

2/2

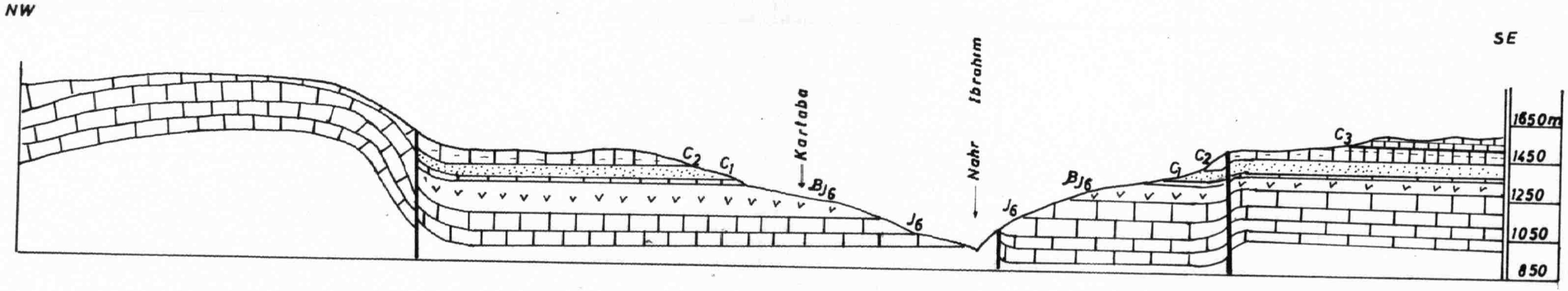
A CROSS SECTION
IN
KARTABA AREA

Ibrahim an Nadi

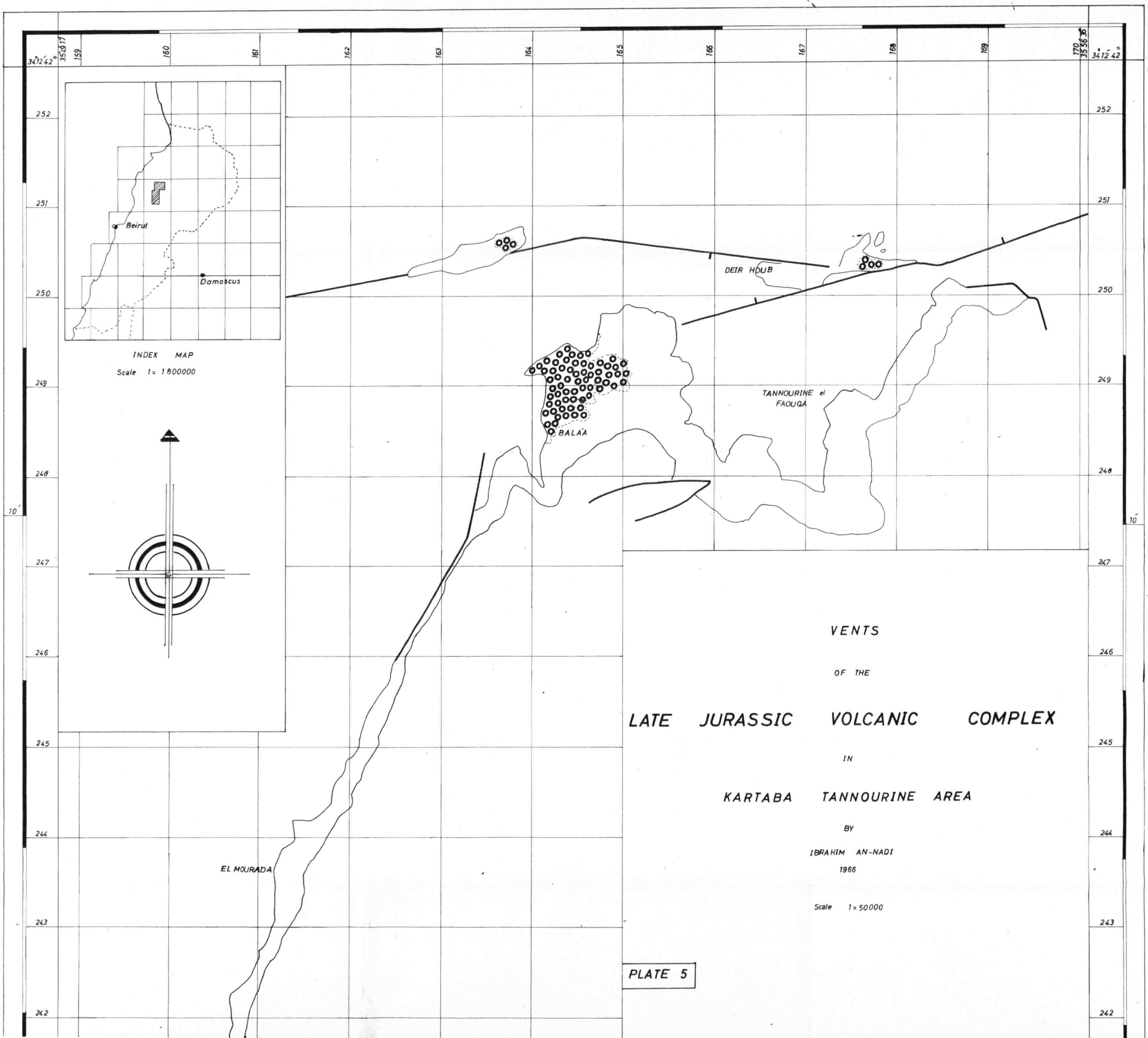
1966

Scale 1:20000

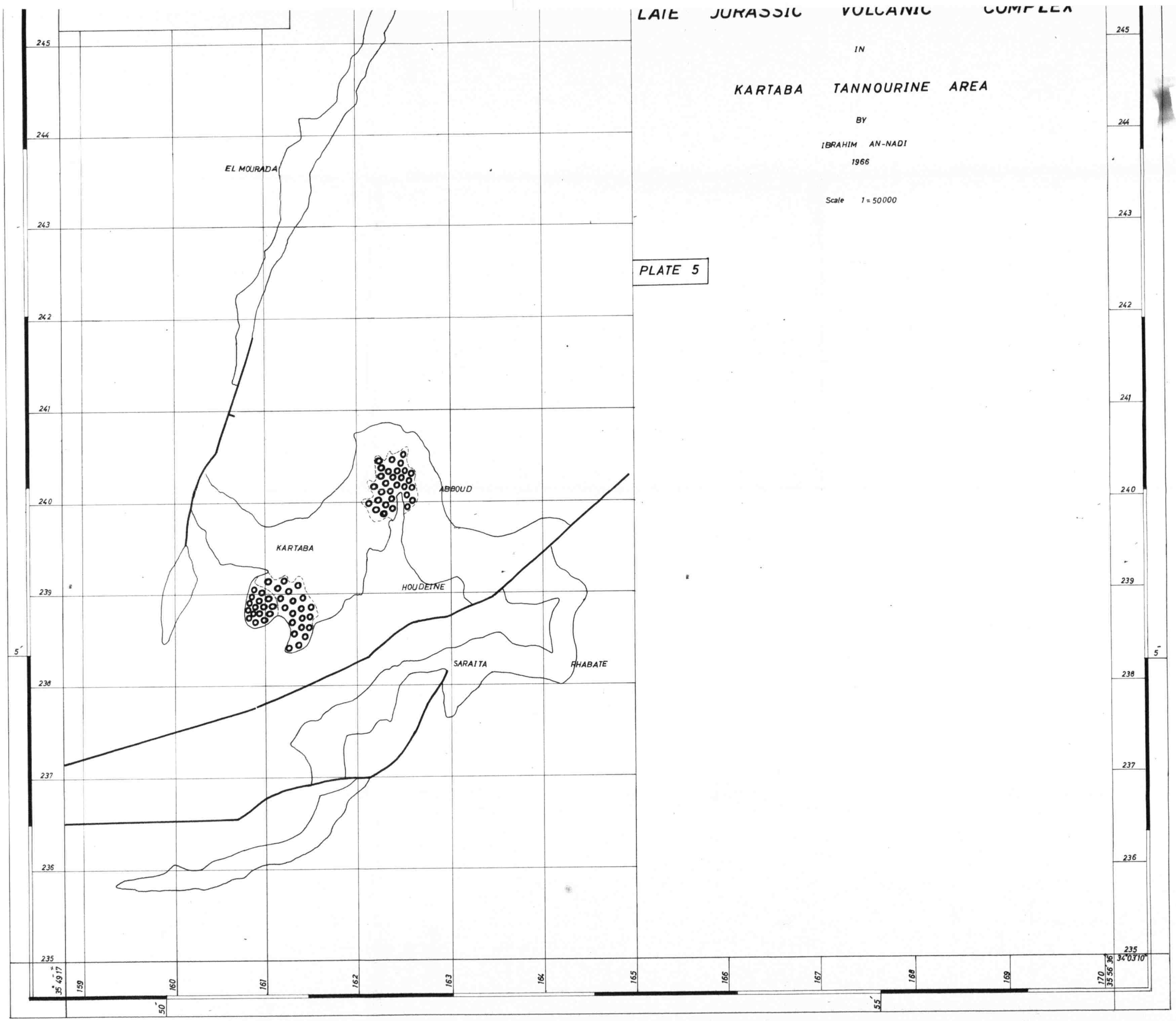
PLATE 4



1/2

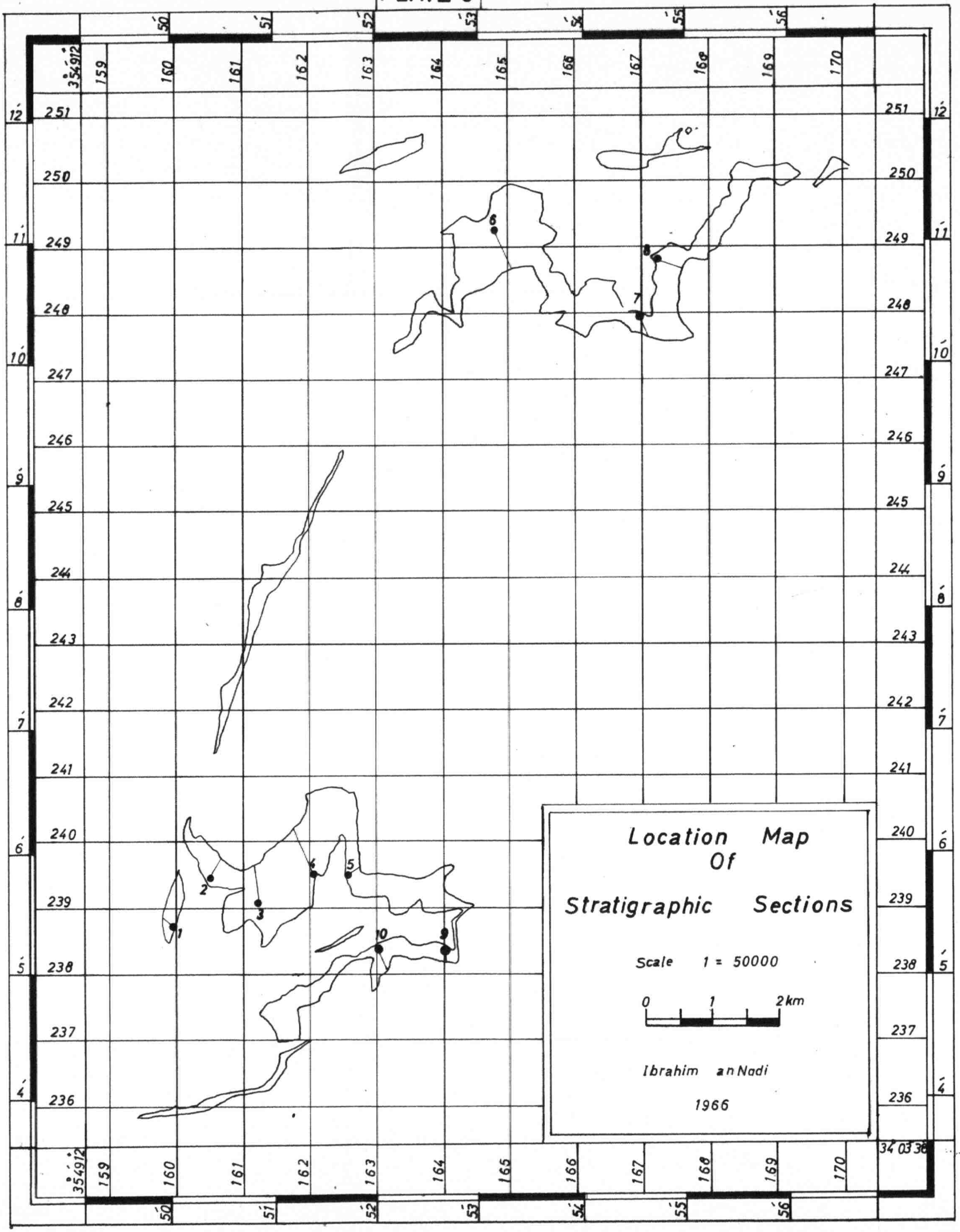


INDEX MAP
Scale 1= 1800000
Beirut
Damascus
DEIR HOUB
TANNOURINE el FAOUQA
BALAA
EL MOURADA
VENTS
OF THE
LATE JURASSIC VOLCANIC COMPLEX
IN
KARTABA TANNOURINE AREA
BY
IBRAHIM AN-NADI
1966
Scale 1= 50000
PLATE 5


LATE JURASSIC VOLCANIC COMPLEX
IN
KARTABA TANNOURINE AREA
BY
IBRAHIM AN-NADI
1966
Scale 1 = 50000
PLATE 5
EL MOURADA
ABBOUD
KARTABA
HOUDEINE
SARAITA
RHABATE

2/2

PLATE 6

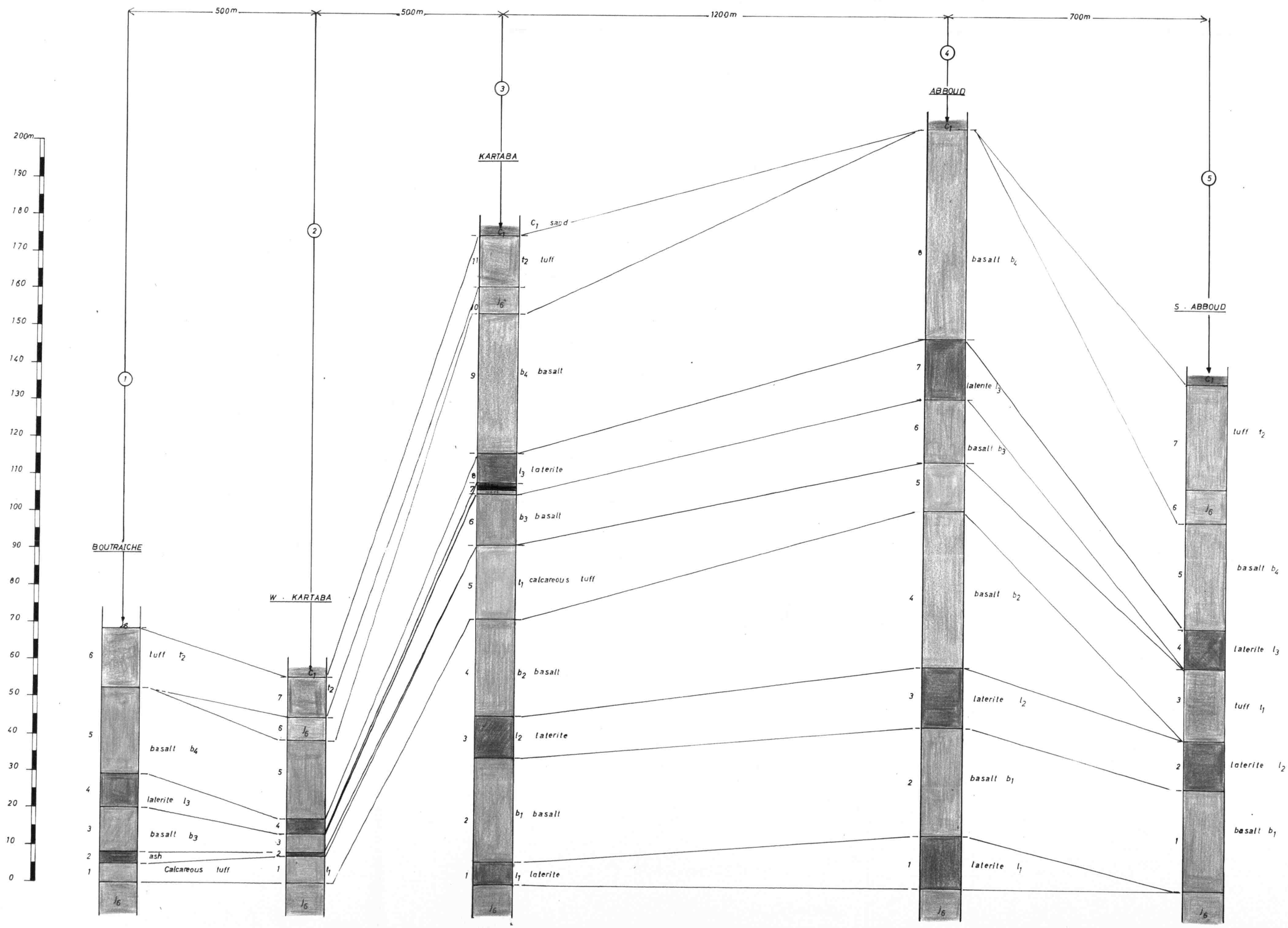

Location Map
Of
Stratigraphic Sections
Scale 1 = 50000
0
1
2 km
Ibrahim an Nadi
1966

STRATIGRAPHIC SECTIONS Of The LATE JURASSIC VOLCANIC COMPLEX In Kartaba Abboud Area

PLATE 7

Ibrahim an Nadi
1966

(SEE THE TEXT FOR DESCRIPTION)



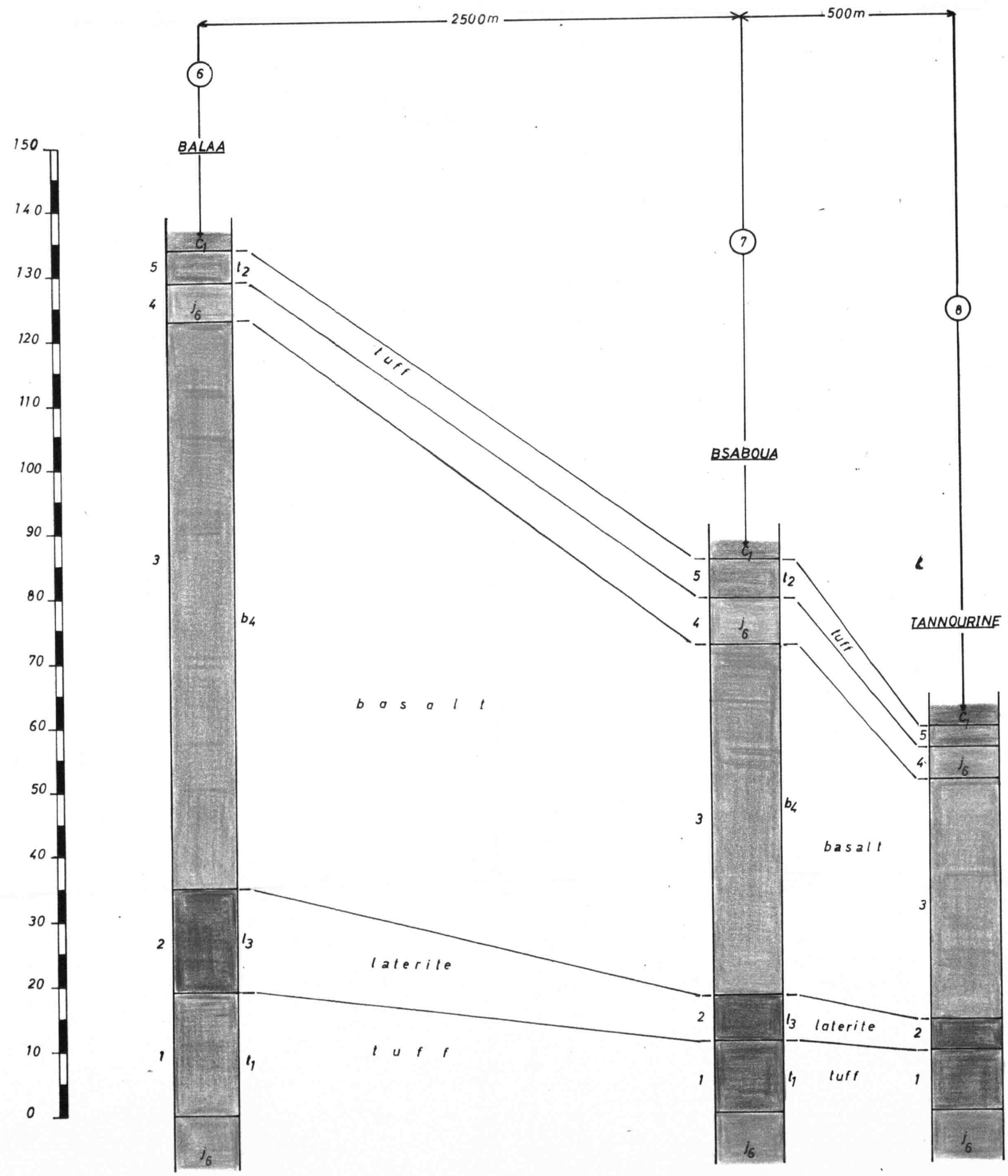
STRATIGRAPHIC SECTIONS Of The LATE JURASSIC VOLCANIC COMPLEX In Balaa Tannourine Area

PLATE 8

Ibrahim an Nadi

1966

(SEE THE TEXT FOR DESCRIPTION)



STRATIGRAPHIC SECTIONS

Of The

LATE JURASSIC VOLCANIC COMPLEX

In

Rhabate Saraita Area

PLATE 9

Ibrahim an Nadi

1966

(SEE THE TEXT FOR DESCRIPTION)