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Progress Report on the Arltunga Nappe Complex

by

A.J. Stewart

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CONTENTS

ILLUSTRATIONS

SUMMARY

The macroscopic form and mesoscopic structures of the western half of the lower nappe of the Arltunga Nappe Complex have been studied as part of an investigation into the mechanisms of emplacement of the nappe.

The nappe consists of a crystalline core of old, heterogeneous, basement rocks and a sedimentary envelope of Heavitree Quartzite and Bitter Springs Formation. The old metamorphic grade of the basement rocks is of the amphibolite facies. However, the subsequent emplacement of these rocks into the core of the nappe was accompanied by greenschist facies metamorphism which resulted in widespread retrogression of the amphibolite facies assemblage. This reactivation also formed new structures in the basement rocks, and these show a progressive variation with distance across the nappe. In the southern or frontal part of the nappe the basement rocks are virtually undeformed, but in the central part a new lineation appears, and this is joined farther to the north by a new foliation. Similarly, the Heavitree Quartzite is undeformed and unmetamorphosed at the southern margin of the nappe (and in the autochthon), but becomes more and more deformed and recrystallized to the north.

It seems that the nappe formed when a block of rocks moved out of the boundary region next to a 'hot spot' in the basement, and travelled a considerable distance over the cooler rocks to the south. The undeformed front of the nappe represents the northernmost part of these cooler rocks, and appears to have been rather passively pushed along by the warmer and more actively deforming rocks in the main part of the nappe.

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INTRODUCTION

The Arltunga Nappe Complex is situated on the north-eastern margin of the Amadeus Basin, in the southern part of the Northern Territory. The complex consists of two fold nappes, a larger on top of a smaller. Each nappe has a crystalline core of old metamorphic basement rocks, and a sedimentary envelope of Heavitree Quartzite and Bitter Springs Formation. Movement of both nappes was from north to south. The complex has been warped about an east-west antiformal axis and a north-south synformal axis, so that the nappes are saddle-shaped. Hence, the present ground surface provides a section through the autochthonous rocks below the nappes, a complete section from bottom to top through the lower nappe (or 'Winnecke Nappe' of Forman et al., 1967), and a section through the lower part of the upper nappe (or 'White Range Nappe' of Forman et al.). The total area of the nappe complex is about 1400 square miles.

The rocks forming the cores of the Arltunga nappes are part of the Arunta Complex, and old Precambrian basement terrain of numerous igneous and metamorphic rock-types. The metamorphic grade of these rocks in the Arltunga area is of the amphibolite facies, and the period of diastrophism which accompanied this regional metamorphism and formed the basement has been termed the Arunta Orogeny. The Arunta Complex is overlain with regional unconformity by the Heavitree Quartzite and Bitter Springs Formation. These are the lowest formations of the Amadeus Basin sequence, which is a sequence of miogeosynclinal shelf sediments laid down from Late Precambrian to Middle Palaeozoic times. The whole area of basement and sediments underwent diastrophism (the Alice Springs Orogeny) in late Devonian to Carboniferous times, and it was during this orogeny that the Arltunga Nappe Complex formed. It is to be stressed that the cores of the Arltunga nappes consist not of metamorphosed sediments of the basin sequence, but of restrivated basement rocks of the Arunta Complex. A preliminary petrographic study of these basement rocks found that greenschist facies metamorphism accompanied the formation of the nappes, and has resulted in widespread retrogression of the old amphibolite facies assemblage of the Arunta Orogeny.

Field work from September 1968 to January 1969 was confirmed to the western half of the nappe complex, and most of the time was spent in the lower nappe. The notes which follow comprise a brief summary of the rock-types in the area, descriptions of the various mesoscopic structures in the core and envelope rocks of the lower nappe, a summary of the changes that take place in these structures with distance across the nappe, and a tentative outline of the sequence of events which led to the emplacement of the nappe.

Lithological Descriptions of Rock Units

1. Basement Rocks

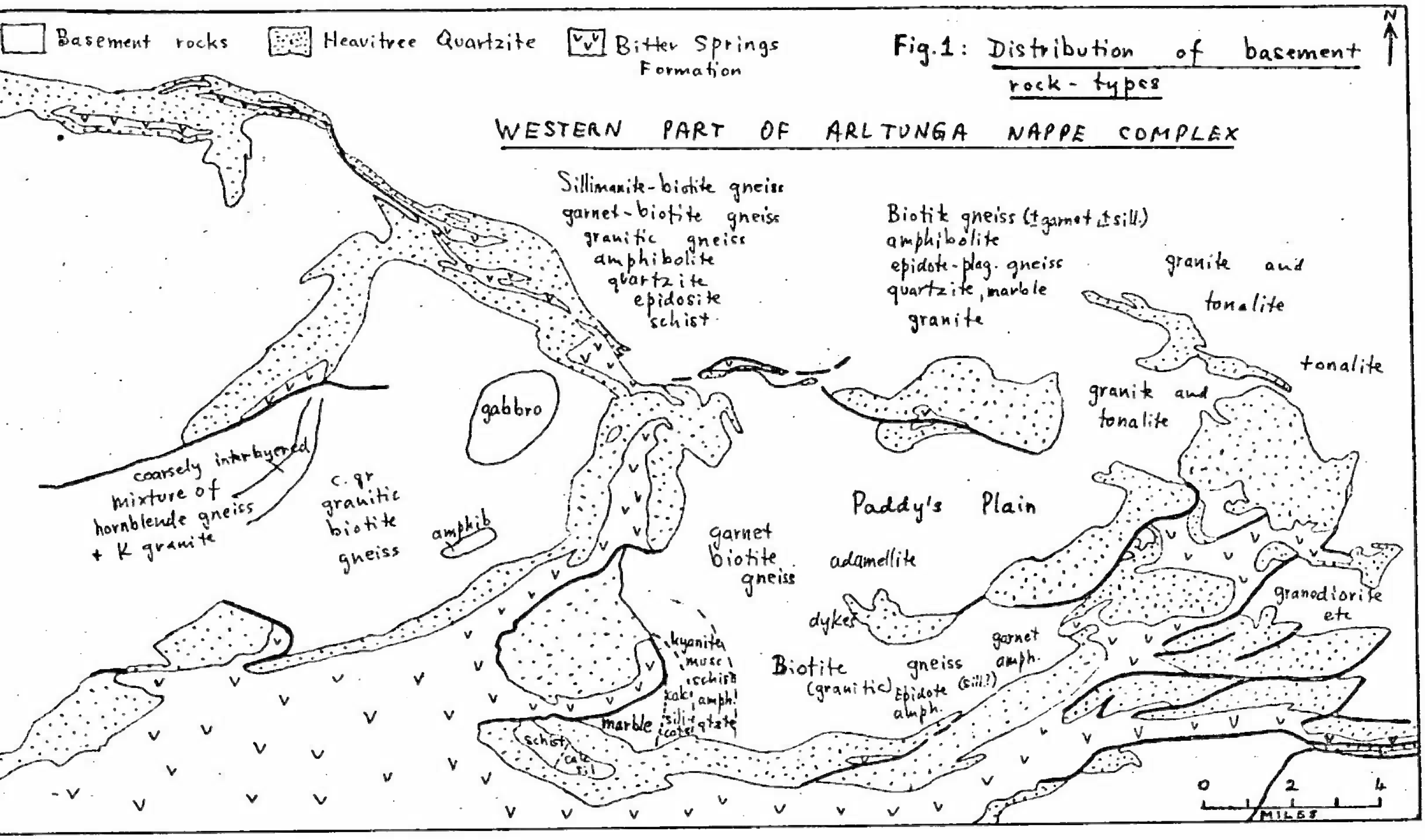
The general distribution of basement rock-types is shown in Figure 1.

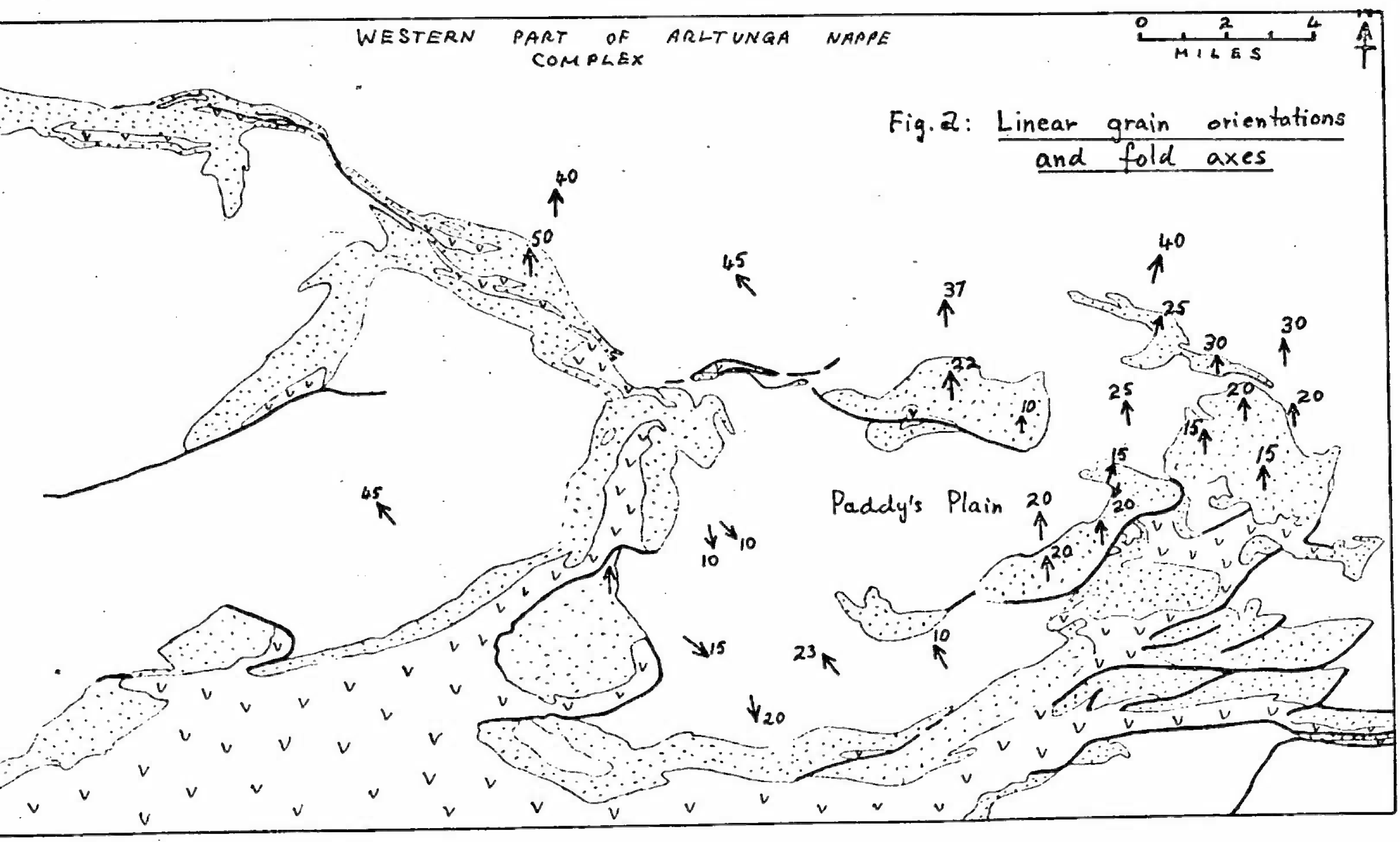
(a) Basement rocks of the autochthon (west of and structually below the lower nappe.

This area consists largely of coarse-grained heterogeneous granitic gneiss accompanied by numerous isolated pods of amphibolite and gneissic diorite, veins and masses of epidosite, and bodies of pegmatite. A large elongate mass of leucocratic granite coarsely interlayered with hornblende gneiss is present in the north-western part of the area, and a body of gabbro cut by numerous veins of pegmatite crops out in the north-eastern part of the area.

(b) Basement rocks of the lower nappe

Many rock-types are present in this area, and very commonly several different varities are found in close proximity to one another, so that lithologic mapping is not possible at this stage. However,





To accompany Record 1969/71.

F 53/A14/106

in general terms the basement rocks can be divided into three main areas of outcrop.

(i) In the western part of the nappe, the commonest rock-types are mica schist (± kyanite), interlayered marble and calc-silicate rocks (with epidote, tremolite-actinolite, and diopside), and amphibolite.

(ii) In the central part of the nappe, biotite gneiss (± garnet, ± sillimanite) is the most abundant rock-type.

(iii) In the eastern part of the nappe, meta-igneous rocks, including tonalite, granite, and granodiorite, are the main lithologies present.

Throughout all three areas there are bodies of amphibolite, quartzite (mottled red, white, and blue), and pegmatite. Isolated dykes of medium-grained adamellite are common in the central part of the nappe.

2. Heavitree Quartzite

The Heavitree Quartzite is composed of three main lithological types, which, though, not mappable, are readily recognized in outcrop. They indicate a gradual decrease in sedimentation and general cleaning up of the formation from bottom to top.

The lower part of the Heavitree Quartzite consists of dirty, coarse-grained, poorly bedded, clayey sandstone, commonly pebbly, and generally with a few score feet of conglomerate at the base. The middle part is a well bedded, medium-grained, blocky sandstone, cross-bedded and ripple-marked. The upper part of the formation is a clean, laminated to thin-bedded, fine-grained sandstone with numerous ripple marks and mud cracks.

3. Bitter Springs Formation

The Bitter Springs Formation consists of dolomite, siltstone, shale, and minor sandstone; only the siltstone at the base of the formation is found in the northern part of the syncline beneath the lower nappe.

Mesoscopic Structures

1. (a) Basement rocks of the autochthon

The mesoscopic structures in the basement rocks of the autochthon were formed during the Arunta Orogeny, and include:

(i) Foliation (lithologic layering, schistosity, and platy grain orientation);

(ii) Lineation (linear grain orientation);

(iii) Folds, mostly narrow, isoclinal folds of large amplitude; superposed folding is present at many localities.

The linear grain orientations and fold axes are plotted in Figure 2.

(b) Basement rocks of the lower nappe

The basement rocks of the lower nappe exhibit structures of two very different ages, viz., old structures which formed during the Arunta Orogeny, and new structures which formed during the Alice Springs Orogeny.

Old structures

These are similar to the mesoscopic structures in the basement rocks of the autochthon, and include foliation, lineation, flow folds, slip folds, and boundinage.

New structures

These include:

(i) Closely spaced fractures in pegmatite bodies;

(ii) Lineation (linear grain orientation) in adamellite dykes;

(iii) Lineation (linear grain orientation) in gneissic rocks with old foliation;

(iv) Lineation (linear grain orientation) and foliation (schistosity) in all the basement rocks, including pegmatite bodies and igneous rocks.

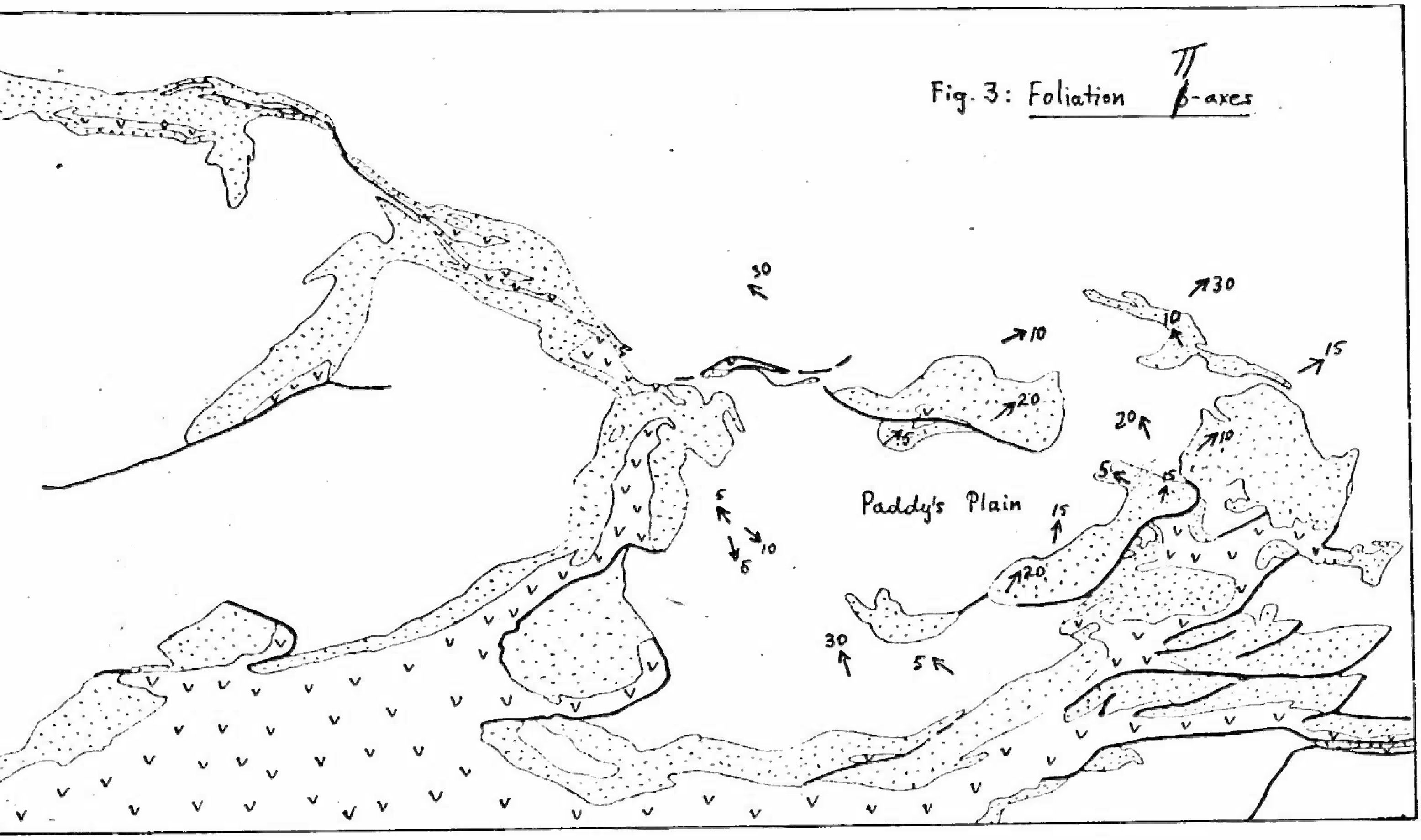


Fig. 3: Foliation π β-axes
30
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Paddy's Plain

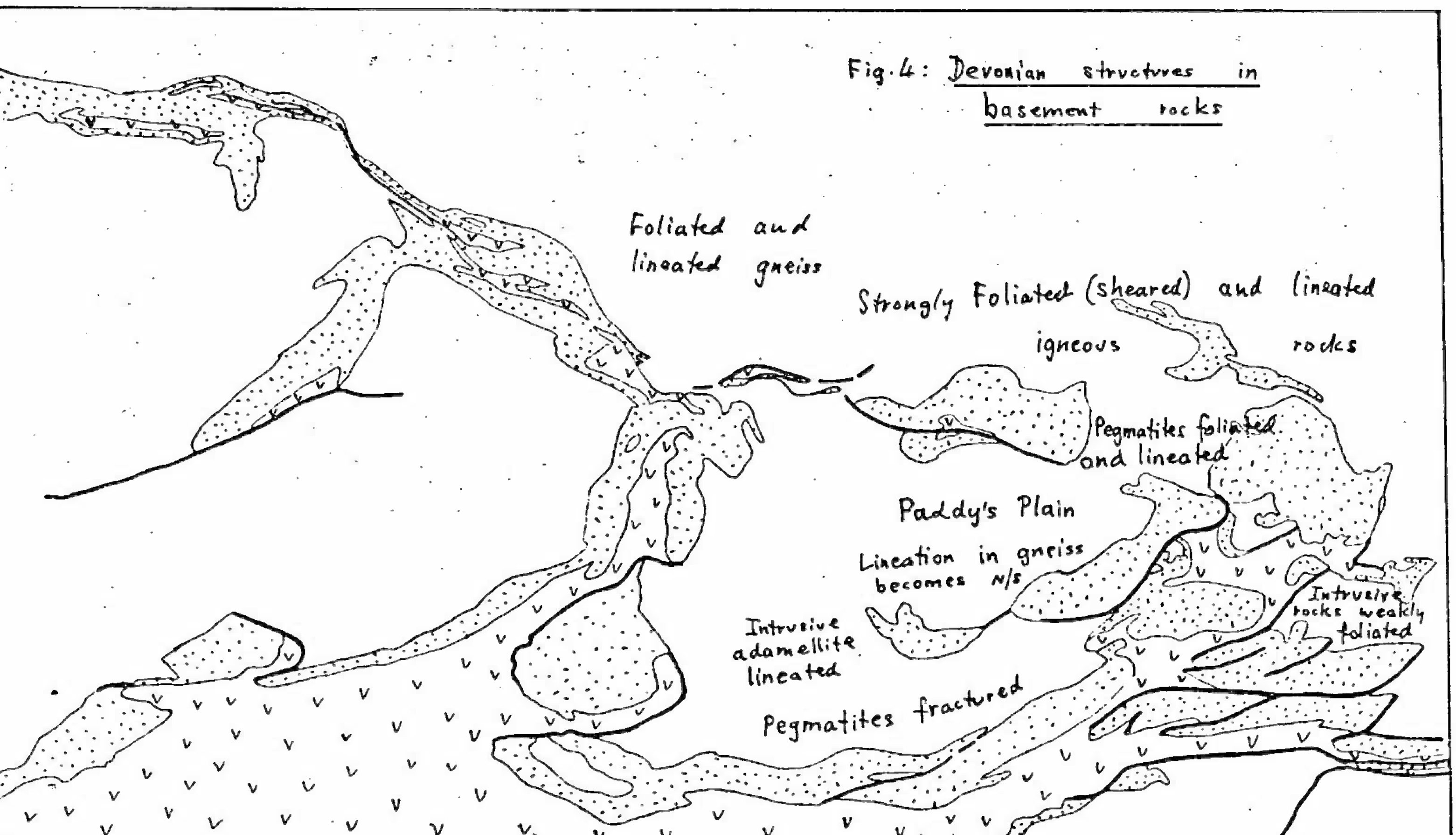

Fig. 4: Devonian structures in basement rocks
Foliated and lineated gneiss
Strongly Foliated (sheared) and lineated igneous rocks
Pegmatites foliated and lineated
Paddy's Plain
Lineation in gneiss becomes N/S
Intrusive adamellite lineated
Intrusive rocks weakly foliated
Pegmatites fractured

The linear grain orientations and foliation π-axis are plotted in Figures 2 and 3.

2. (a) Heavitree Quartzite of the autochthon

The Heavitree Quartzite of the autochthon is undeformed, and exhibits no penetrative structures; ripple marks, mud cracks, and cavities from which euhedral crystals of pyrite have weathered out show no sign of deformation.

(b) Heavitree Quartzite of the lower nappe

Mesoscopic structures in the Heavitree Quartzite of the lower nappe were all formed during the Alice Springs Orogeny, and include:

(i) Uneveness of bedding, and brecciation;

(ii) Foliation (schistosity) and lineation (linear grain orientation); the lineation lies in the plane of the White Range. Foliation π axis and linear grain orientations are plotted in Figures 2 and 3.

(iii) Boudinage, with axes plunging gently east;

(iv) Reclined isoclinel folds, with axes plunging gently north parallel to the linear grain orientation and axial planes dippling gently north parallel to the foliation. In places these folds are disrupted and boudinaged, so that isolated fold noses are surrounded by lineated schist, but are still oriented northsouth with a gently northerly plunge. Some fold axes are oriented east-west, and plunge gently east parallel to the east-west boudins.

(v) Close, concentric to disharmonic folds, with east-west axes plunging gently east and axial planes which are generally vertical but which can range in dip from 60° north to 60° south. The concentric folds are concentrated in the well-bedded, medium-grained quartzite, whereas the disharmonic folds are found in the laminated to thin-bedded upper part of the quartzite; the disharmonic folds are smaller than the concentric folds, and are commonly isoclinal. These east-west folds cross-fold the north-south isoclinal folds, and hence post-date them.

(vi) Kink bands, mostly striking east-west and dippling south at 60° to 70°. Kink bands of the north-dipping conjugate set are found in some places, and a north-south set of kink bands with dip close to vertical is also fairly commonly found in association with the east-west set.

Changes in the structures with distance across the nappe

1. New structures in the basement rocks of the nappe. (Figure 4)

(i) Fracture surfaces in the pegmatite bodies are only found in the southern part of the nappe.

(ii) Lineation without foliation is also restricted to the southern part of the nappe, but it is found somewhat to the north of the fractured pegmatite bodies. It is seen mainly in the dykes of intrusive adamillite; under the microscope the feldspar grains are bent and broken, and the quartz grains elongated.

(iii) In the southern part of the nappe, lineation and foliation in the gneissic rocks show no relation to the macroscopic form of the nappe, and hence are regarded as old structures which formed during the Arunta Orogeny. However, in the central part of the nappe the lineation in the gneissic rocks takes up a north-south trend, with a gentle northerly plunge, parallel to the lineation trend throughout the northern half of the nappe.

(iv) The new foliation (gently north-dipping) appears in the igneous rocks in the northern half of the nappe, and is accompanied by the north-plunging lineation. Both these structures become more intense to the north. The foliation of the old gneisses tends to acquire an east-west strike and northerly dip also. Under the microscope, plagioclase is found to have altered to albite + epidote + muscovite, and quartz has recrystallized to polygonal mosaics of grains which show some preferred dimensional orientation.

2. Structures in the Heavitree Quartzite of the nappe

Lines showing the position of the first entry of various structures in the Heavitree Quartzite of the lower nappe are shown in Figure 5. Moving from south to north we see:

(i) Deformation lamellae in the quartz grains of the Heavitree Quartzite at the southern edge of the nappe, and irregular quartz viens with diffuse margins are common in the sandstone. Pseudopebbles in the sandstone are undeformed.

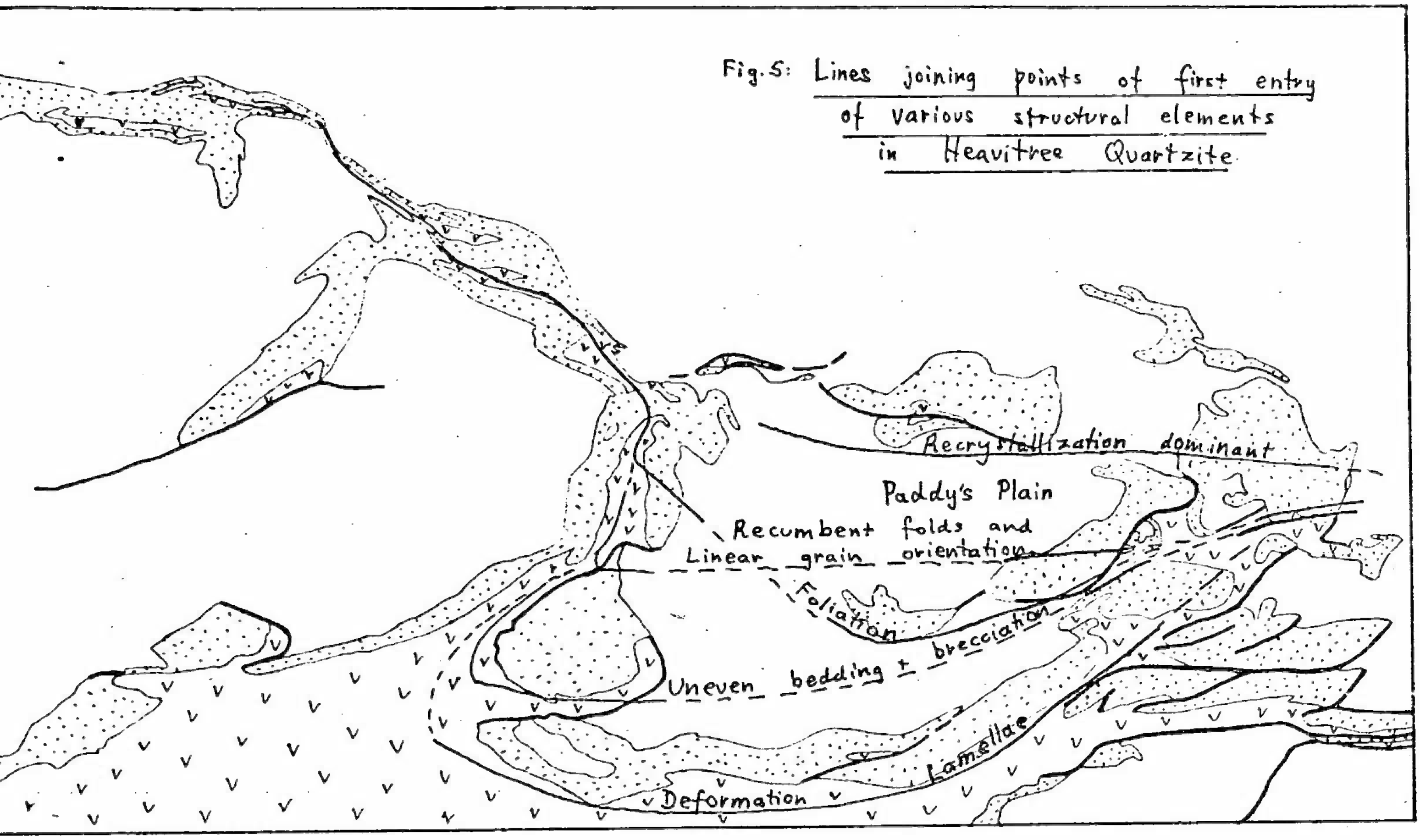

Fig. 5: Lines joining points of first entry of various structural elements in Heavitree Quartzite

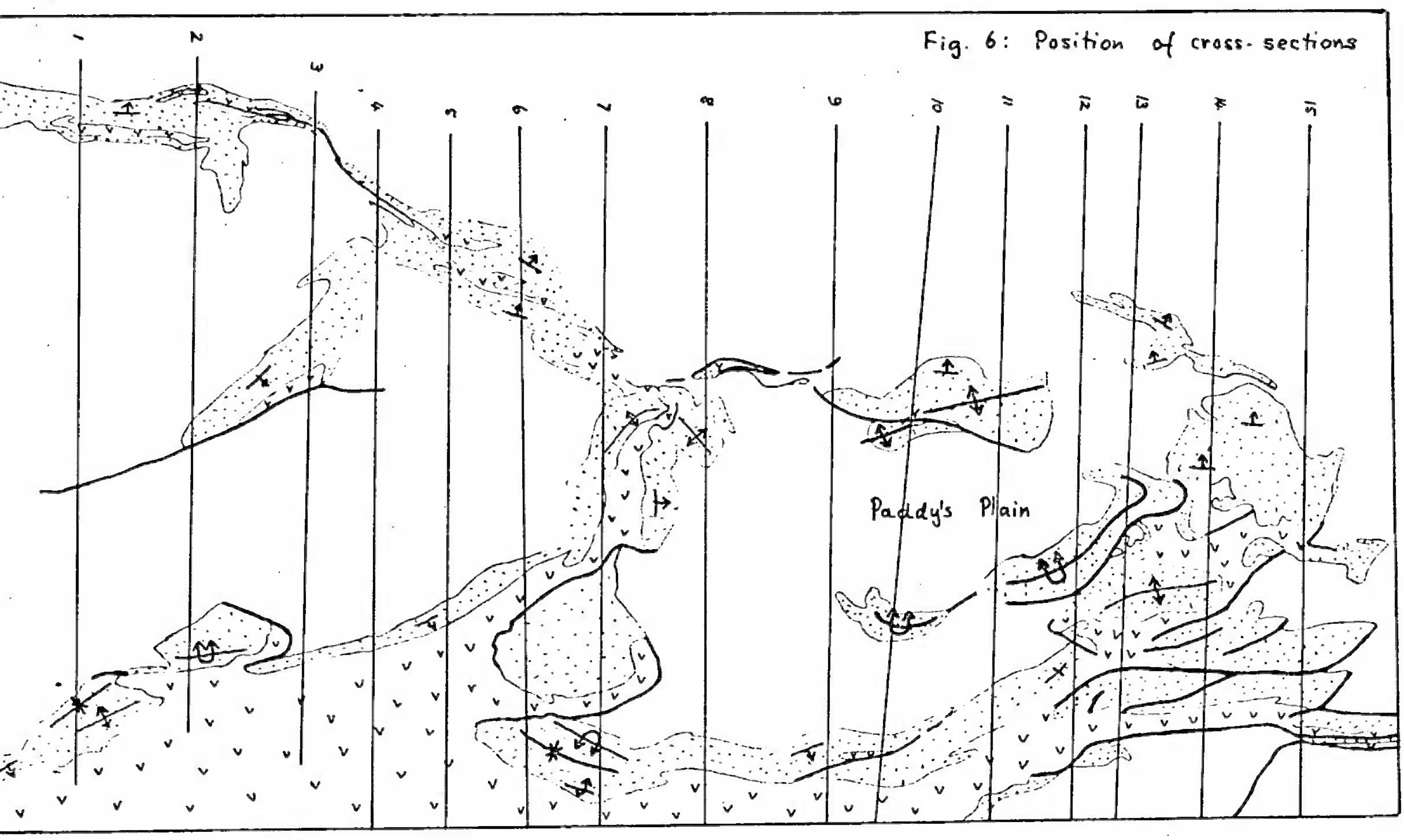

Fig. 6: Position of cross-sections

To accompany Record 1969/71

F53/A14/108

(ii) The bedding becomes uneven, and in places the quartzite is brecciated. Quartz veins have sharp, well defined margins.

(iii) Foliation (gently north-dipping) without lineation is found in the quartzite ranges south of Paddy's Plain. These quartzite ranges are the boudinaged remnants of an antiformal involution projecting up from the lower limb of the nappe, and the foliation in the quartzite shows no geometric relation to this antiform (such as fanning around the axial plain). Pseudopebbles in the quartzite have been deformed into oblate ellipsoids of revolution which lie in the plane of the foliation and show a strain of about 35%. Bedding is still clearly recognizable. The quartzite contains abundant fine-grained sericite.

(iv) North-dipping foliation, notrh-plunging lineation, and north-plunging isoclinal reclined folds are found in the quartzite ranges on the north side of Paddy's Plain and in the north-eastern end of the range on the south side of Paddy's Plain. In the western part of the nappe the lineation enters before the foliation. Sericite in the quartzite is coarser-grained, and conglomerate pebbles show considerable strain, with north-south elongations of several hundred percent; east-west elongations of the pebbles are also present, but are only a fraction of the value of the north-south elongations.

(v) The lineation and foliation become more intense to the north. Sericite continues to increase in grain size, and in places there are large irregular bodies in the quartzite consisting of a mass of blebby segregations of white vein quartz and green sericite.

Conclusions from structural data

1. A temperature gradient existed in the nappe during its emplacement; the rocks were cooler in the south (100° to 200°C?) and warmer in the north (350° to 450°C?).

2. A strain gradient existed in the nappe during its emplacement, ranging from virtually zero in the south to several hundred percent in the north.

3. The consistent north-south orientation of the reclined isoclinal folds and linear grain orientation in the northern half of the nappe indicates accelerated flow, which suggests the existence of an east-west constriction during the emplacement of that part of the nappe.

4. The gently north-dipping foliation in the quartzite south of Paddy's Plain is a cross-cutting foliation which post-dates the formation of the antiformal involution; the oblate ellipsoidal shape of the deformed pseudopebbles in the plane of the foliation indicates a near-vertical flattening.

Tentative sequence of events

1. Greenschist facies metamorphism affected the rocks noth of the present position of the Arltunga Nappe Complex, and was preceded, accompanied, or followed by th imposition of a compressive stress field with its principal acis oriented north-south.

2. The first nappe started to move south in response to the imposed stress. Movement was concentrated in the boundary region between the cooler and warmer rocks, and as the nappe moved up and out of the autochthon it 'clipped off' a piece from the northmost region of cooler rock and carried it along at the front of the nappe. This body of cool rock fractured to some extent, but underwent very little strain. In contrast, the rocks in the following part of the nappe were warmer, and underwent consiserable strain; lineation and foliation formed by the elongation and flattening of grains and pebbles. When the nappe was about half emplaced, the intermediate compressive stress increased sufficiently to form the gently north-plunging isoclinal reclined folds, and eventually bent the whole nappe into a synformal shape with a north-south axis. Towards the end of the emplacement, the resistance of the rocks surrounding the nappe became sufficient to cause a 'pile-up' of the warmer rocks behind the block of cool rocks at the front of the nappe, thus forming the antiformal involution along the northern side of the cool region.

3. After emplacement was completed and the nappe had cooled and stiffened to some extent, the remaining north-south stress formed the east-west concentric to disharmonic folds, thus folding the lineation, foliation, and north-south folds which had formed during the emplacement. The last residual stresses gave rise to the east-west and north-south sets of kink bands.

4. Subsequently, the second nappe was emplaced on top of the first, and formed the cross-cutting foliation and flattened the pseudo-pebbles in the quartzite of the antiformal involution.

5. Finally, the whole nappe complex was warped about an antiformal east-west axis through its centre. A series of north-south cross-sections across the lower nappe is shown in Figures 6 and 7.

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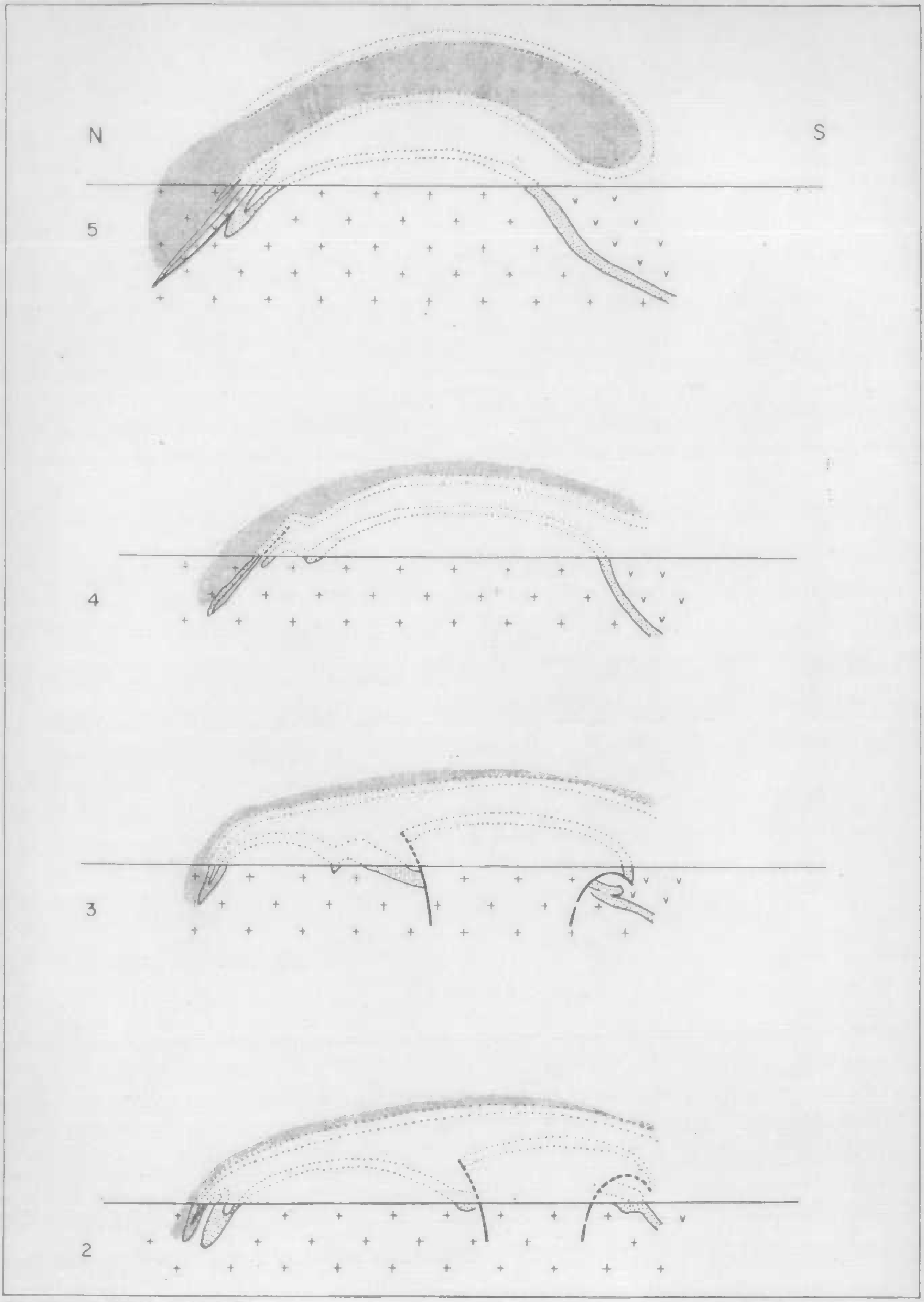
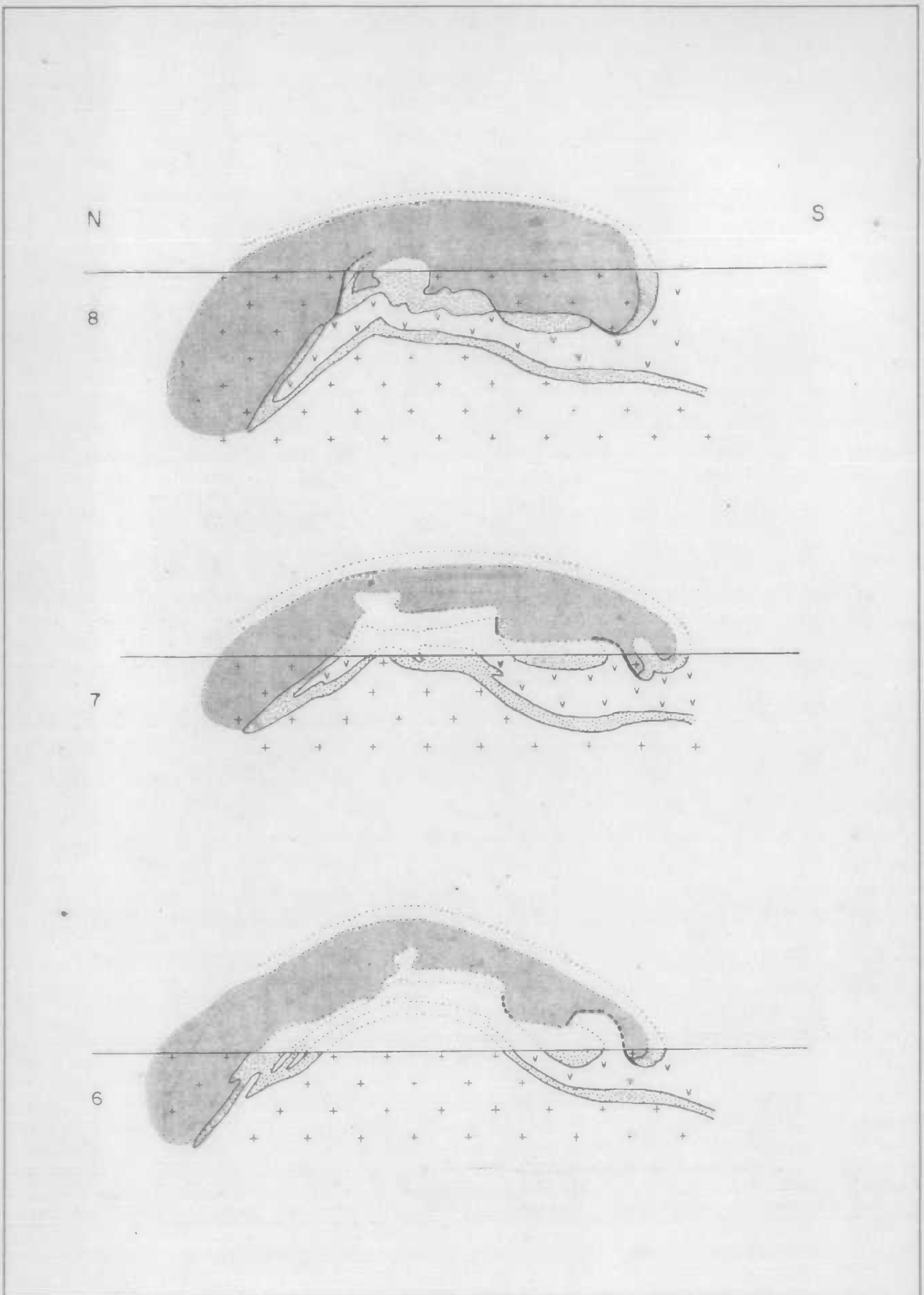


To accompany Record No 1969/71

F53/A14/109

Fig. 7a. Cross sections



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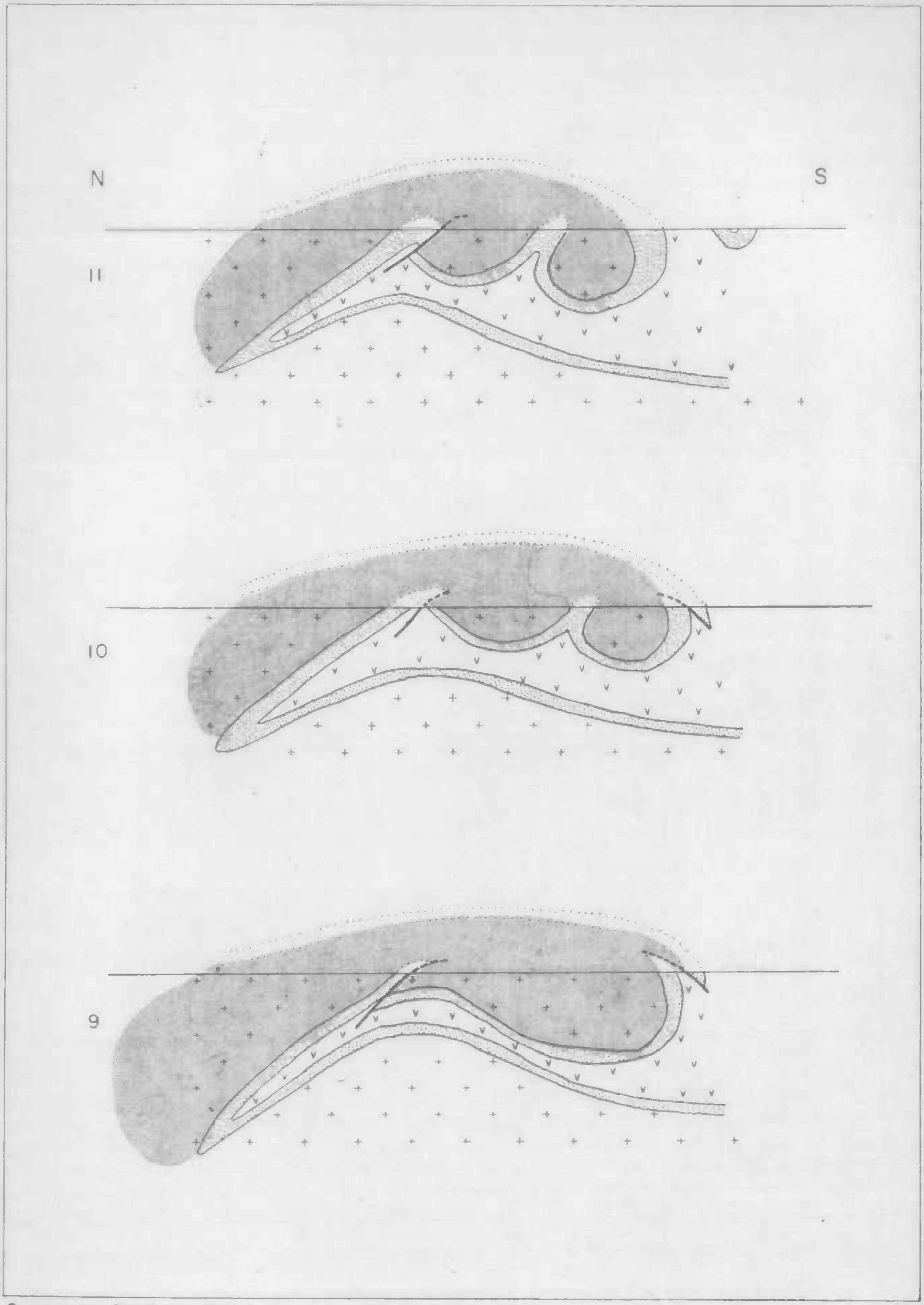
F53/A14/109

Fig. 7b. Cross sections



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F53/A14/109

Fig. 7c. Cross sections

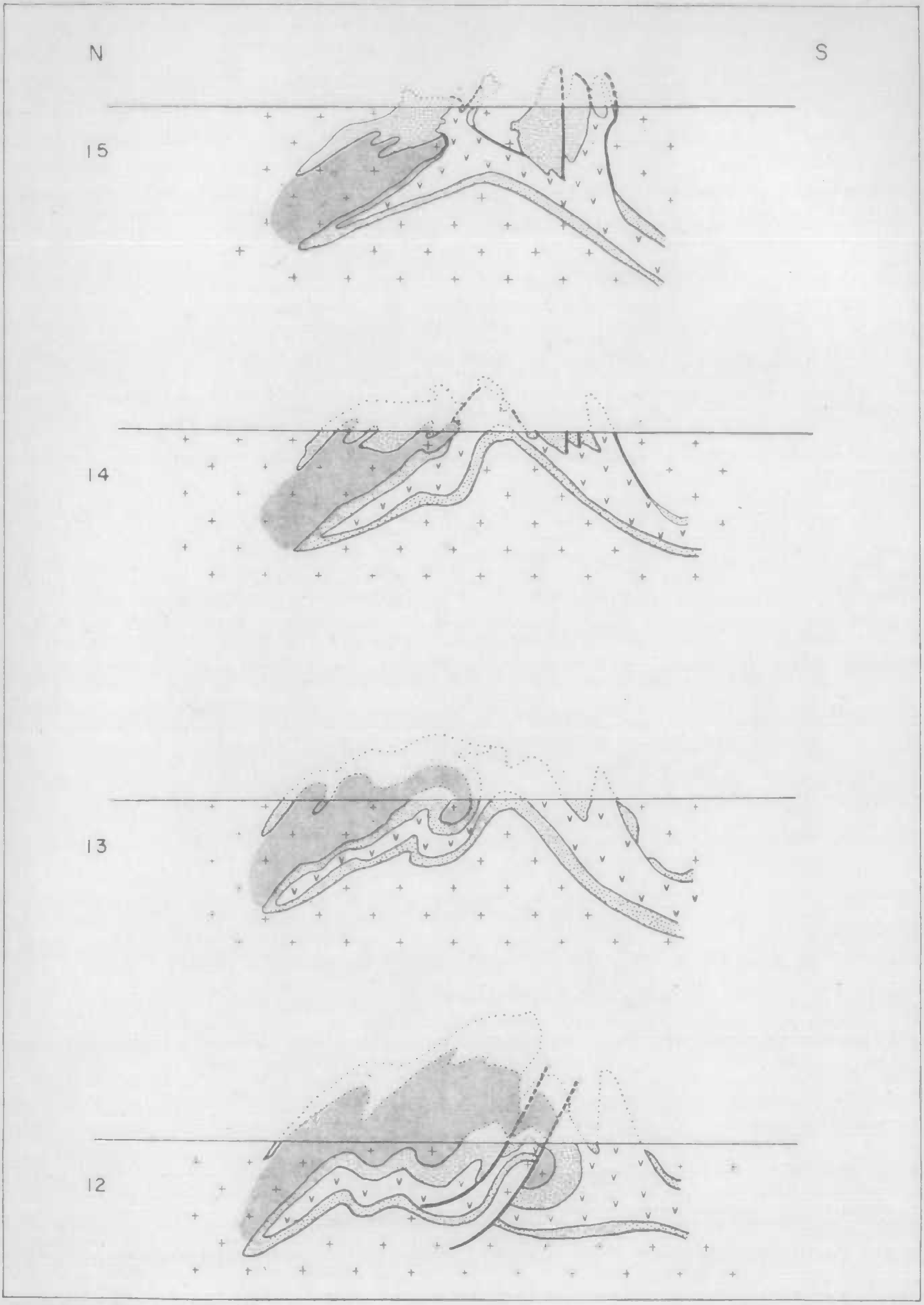

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Fig. 7d. Cross sections