THE PHOTOGEOLOGICAL CHARACTERISTICS OF CARBONIFEROUS LIMESTONE IN BRITAIN

İngiltere'deki Karbonifer Kireçtaşı'nın Foto jeolojik ozeîliïderi

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ABSTRACT: Some relations between the photographic appearance and the physical characteristics of the Carboniferous Limestone were found, and consequently a better understanding could be obtained in a limestone terrain-

ÖZ: Bu çalışma ile Karbonifer Kiteçtaşlannın fiziksel özellikleri ile hava fotoğraflarındaki görünüşleri arasında bazı ilişkiler bulunmuş ve bu şekilde, bir kireçtaşı arazisinm daha iyi anlaşılması olanağı sağlanmıştır.

INTRODUCTION

The lower part of Carboniferous system is made up almost entirely of limestone which is the subject of the present investigation.

The Carboniferous limestone occupies consaderable areas throughout the country. Almost 2/3 of all limestone outcrops are of Carboniferous age. The areas chosen for this investigation have shown that a lot of information can be obtained through the study of their air photographs.

This paper reports an attempt to learn more about photogeological characteristics of Carbomferous Limestone in'Britain.'

PREVIOUS WORK

So far, no specific investigation carried out in this field has appeard except for the doctorate thesis of Norman (1968).

Although the thesis "describes am investigation of the geological causes and influences affecting the existance of linear features seen on air photographts of areas where the bedrock is obscured by

superficial deposits", some parts of the investigation were made in the area of Carboniferous limestone.

The following year, Norman alid Waltham (1969) deseribed "the air photograph appearance of karst features with emphasis on those related to underground openings in Northern England". This is the first and only published paper dealing with the Carboniferous Limestone.

In the same year, photographs of areas covered by boulder clay were attached to the paper of Norman (1969), In the explanations of these photographs, the Interpretation of some buried linear features of Carboniferous Limestones were described.

METHODS AN» PROCEDURES

A large part of the British Isles are covered by extensive glacial deposits and this superficial cover tends to mask the geology underneath. To avoid misinterpretation, the most representative areas not covered by the glacial drift were selected. From these suitable localities for photo interpretation, the areas where Carboniferous Limestone is fully developed were chosen.

The Carboniferous Limestone exposures along the coasts of Gower, Pembrokeshire and Anglesey were chosen in addition to the outcrops in the Mendip Hills (Bristol district), Pennines (Derbyshire), and Ingleborough (Yorkshire).

The method of investigation was divided into three stages.

(i) The photographs were examined under a Bulger and Watts SB 180 mirror stereoscope and the interpretations on the prints were annotated when using stereovision.

(ii) The annotated information was correlated with the field work, or geological maps, or with both.

(iii) The data collected from the field work, air photographs and geological literature were used for analysis.

The main source of information was the publications of the Geological Survey of Great Britain.

The air photographs used in this investigation were taken by the Royal Air Force.

TONAL CHAIIACTEMSTIOS

The tonal relations of a geological unit hold only locally, and even on successive photographs the same object may appear in variable tones. Therefore» it is not possible to give rules for the identification of ground features by to'ne alone, but as far as conventional black and white (panchromatic) photographs are concerned in present investigation, the photographic tone may act as a valuable contribution in recognition and interpretation of Carboniferous Limestone on air photographs.

The study of photographic tones in the Carboniferous Limestone areas showed that,—

(i) The light grey tone is common for the exposed limestone rock similar to any limestone terrain dn humid areas.

(ii) In those parts of the study areas covered with considerable soil, the photographic tones are rather dark grey.

(iii) The presence of shales and cherts also changes the overall tone from light to dark and mottled. The reef limestones show irregular light and dark grey tones, while the black Mmestones reveal rather white to near white photographic tone.

(iy) The light tone is also broken by the occurrences of dark spots or patches which mark the sinkholes.

THE REUDEF OF OARBOMFEEOUS IJDH0B8TONE AREAS

The general appearance of the Carboniferous Limestone on air photographs may be said to be representative of the scenery developed on similar Mmestones in other parts of the world. In the case of Britain, the extensive development of limestone features occurred when the rocks ware part of a humid region.

Since the landsforms in limestone areas result from regional variations of climate and vegetation, in addition to the physical properties of the limestones themselves, the degree of denudation of Carboniferous limestone is quite extensive and produces an area of subdued topography rather than a bold relief.

Karstic features can be seen in almost every Carboniferous limestone district with or without overburden. Consequently, collapse structures are common and can be seen in most areas.

In the areas of bare rock surfaces, the nature of the Carboniferous Limestone is typified by the appearance of the extensive development of fracturing. ,

In a number of areas, the Carbiniferous limestone is masked by sperficial cover and the rock surfaces cannot be seen. However, it forms an upland area with a broad belt of rounded hills, cut steeply sided valleys.

The numerous lead-zénc mining excavations are also typical for many Carboniferous Limestone landscapes, and show as a number of lodes pitted by minors.

LFTHOLOGIGAL CHARACTERISTICS

The Carboniferous Limestone includes beds of varied character ranging from massive limestone and alternations of limestones, Bandstones and shales to dolomites and dolomitic limestones and reef limestones. However, »it is generally known as a massive or thickly bedded limestone giving rise to varied landscape. The shale bands, calcite-mudstone lenses and minor cherts occur frequently in several horizons, but they are always subordinate in extent to the limestone and tend to be impersistent laterally.

Different limestones exhibit differing expressions on air photographs as they hava various characteristics. Some specific criteria for recognition of various limestones or the changes facies within the litho-stratigraphic unit can be detected.

The studies of lithologie variations in the Carboniferous Limestone on the air photographs showed that,— ,

(i) The current subdivisions of the Carboniferous limestone are not always suitable for a photographic interpretation study, since this classification is based on mainly faunal zones and since there is no marked boundary between the divisions as differentiated in faunal classifcation (Özmumcu, 1971).

(ii) Instead, recognition features have been found for various types of Carboniferous Limestone. However, these features are local in application and should not be accepted as a general guide for all areas.

(im) The masking effect of superficial cover on the Carboniferous Limestone outcrops made the interpretation difficult on many photographs, but in areas covered with only a thin soil, the recognition of units was quite easy.

(iv) Attempts to find a relationship between the vegetation over the Carboniferous Limestone areas and the lithology were

made, but no reliable recignition features were found to detect the lithologies by means of the plant community alone on the panchromatic photography available.

BOUNDARY CHARACTERISTICS

In the stratigraphie column, the Carboniferous Limestone rests on a set of sandstone and shale beds (Old Red Sandstone)[1] and overlain by another sandstone with shale intercalations (Millstone Grit)[1]. However, this is not always the same in every exposures of Carboniferous Limestone.

In many areas studies, the Carboniferous Limestone is conformably succeed by Devonian of Old Red Sandstone fades as seen in the south-west. Elsewhere i.e. in the 'north of England, and in North Wales (Anglesey) the Old Red Sandstone is absent, and an angular unconformity is found on a evenly eroded surface of older rocks, e.g. Ordovician, Silurian and Pre-Cambrian rocks (Ingletonian Series, Mona Complex).

The Millstone Grit —Namurian in age— rests unconformably on some Carboniferous Limestone outcrops studied in the southwest and in Derbyshire. But in the northern Peimines (particularly at Ingleborough), it succeeds the Yoredale faciès formed by intercalations of limestones, shales and sandstones (cyclic sedimentation). The Carboniferous limestone emerges beneath a covering of Triassie strata (Keuper Marls) to form the Mendips.

The Carboniferous Limestone landscapes could be easily distinguished from other terrains and the boundary could be detected quite accurately. As far as boundary characteristics are concerned, the study of photographs revealed that,—

(i) The boundaries with the sedimentary rocks, e.g. Ordoviöian shales, Old Red Sandstone, Millstone Grit and Keuper Marl, showed no transitional zone, but were linear instead, although Iiang, et al. (1J951) described the presence of a transitional zone.. It is believed that the lack of well exposed surfaces of Carboniferous Limestone is responsibe for this statement.

(1) The term "Old Red Sandstne" has frequently been used in a stratigraphie sense. It is essentially a descriptive term while much of the succession is not red nor is it entirely sandstone. The term "Millstone Grit" refers to rocks of deltaic faciès, forming coarse sandstones (grits) interbedded with marine shales (Bennison and Wright, 1969).

(ii) The boundaries with the metamorphics, e.g. Mona Complex and Ingletonian Series, were almost the same, i.e. linear.

However, the adjacent rocks could be differentiated by their own pronounced photographic characteristics controlled mostly by differential erosion and lithological constituents.

(iii) The dolerites which are applied to fresh basaltic rocks are confined to the main body of the Carboniferous limestone at some localities. Although the doleiites have caused thermal alteration to the Carboniferous Limestone at the contacts, it has not been detected on the phoographs studied because of the small outcrops and the thick soil cover.

FRACTURE TRACE CHARACTERISTICS

The study of fracture traces has been focused mainly on two types of characteristics, qualitative information (manifestations of fractures) and quantitative statistics (orientations, frekuencies and densities of fractures) rather than on their causes.

The term "trace" needs to be explained as it i$ widely used throughout the present work. By fracture is meant a break in the rocks. This must be observed on bara rock surfaces. The actual fractures, in fact, may not be seen in covered terrain. On the photographs of these areas* the linear features seen are only the surface expressiolns or traces of tba hidden fractures. From this point of view, he erm "fracure race" is used here to refer to the photo-manifestation of joints and faults.

Fracture trace analysis on Carboniferous Limestone areas showed that, —

(i) According to the comparison of the drainage air photo fracture trace maps, the fracturing in the Carboniferous Limestone area (northern part of the Derbyshire dome) commonly controls the drainage.

(ii) Tbe fracture patterns in every individual bed or horizon of Carboniferous limestone exhibit different patterns from that in the bed above or below, and easily seen on bare rock surfaces of the area (the Ingleborough district).

The following factors may be responsible for the variations in the pattern of fractures, (a) the thickness of individual beds, (b) the grain size and texture of the limestones, (c) the stress involved during folding and faulting.

(iii) A more detailed study was carried out on the fracture traces displayed in the Ingleborough (Fig. 1) in order to analysis the fracture pattern on the Great Scar Limestone[1] and the adjacent areas, the overlying Yoredale series and underlying Ingletonian series. The emphasis was placed upon the fractures which have

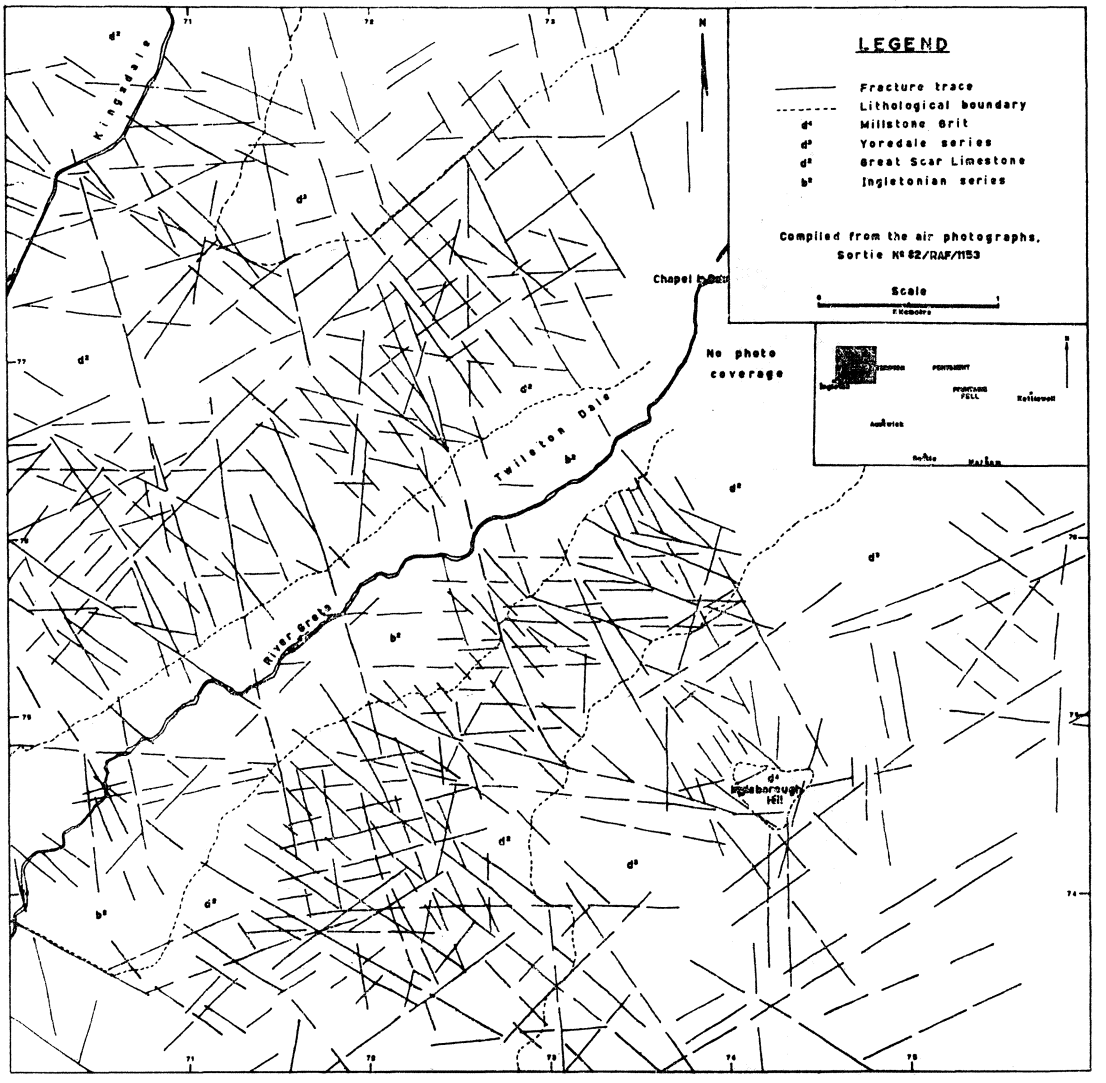

Fig. 1. Fracture trace map of a part of the Ingleboroiigh district*

been interpreted on the photographs without stereoscopic examination. The lengths of individual fractures were measured in metres, The directions of the fractures were plotted in lfrdegree sectors. From these measurements histograms and rose diagrams were constructed (Fig. 2, 3),

(1) **The Carboniferous** Limestone is **called locally** as **the** Great Scar Limestone dn **the** northern England.

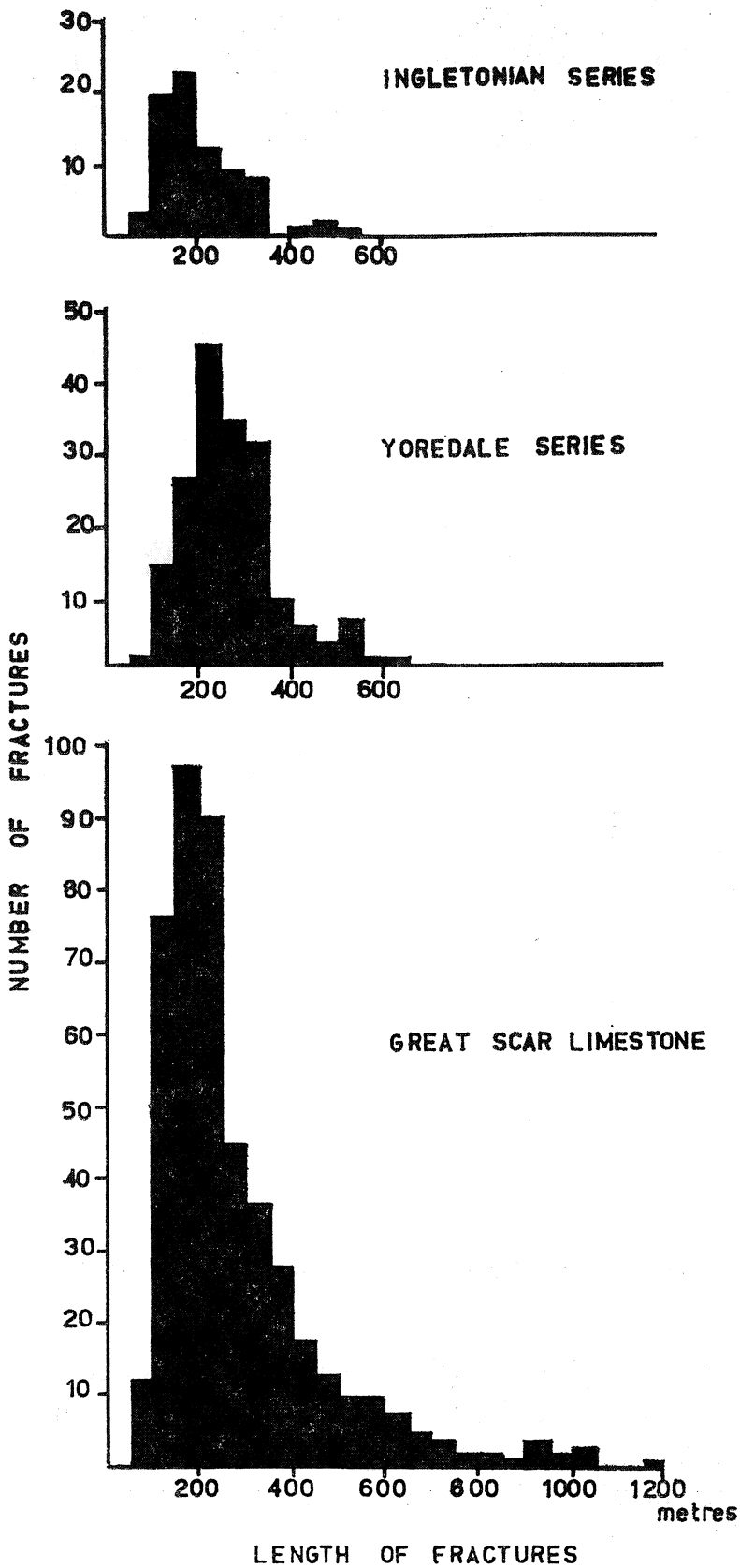

Fig. 2. Histogram of fracture trace length frequency distribution.

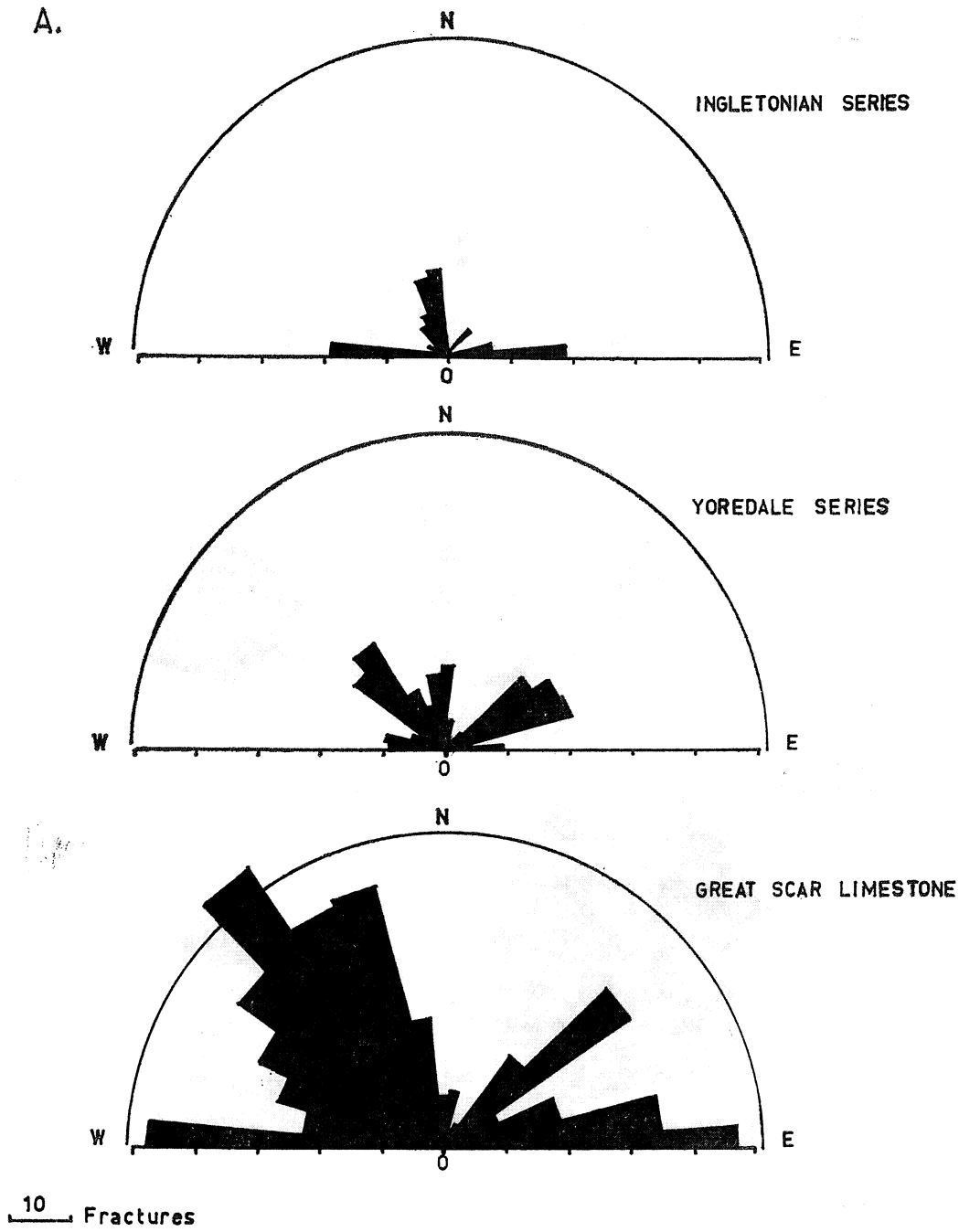

Fig. 3-A. Rose diagam of fracture trace directional frequency distribution.

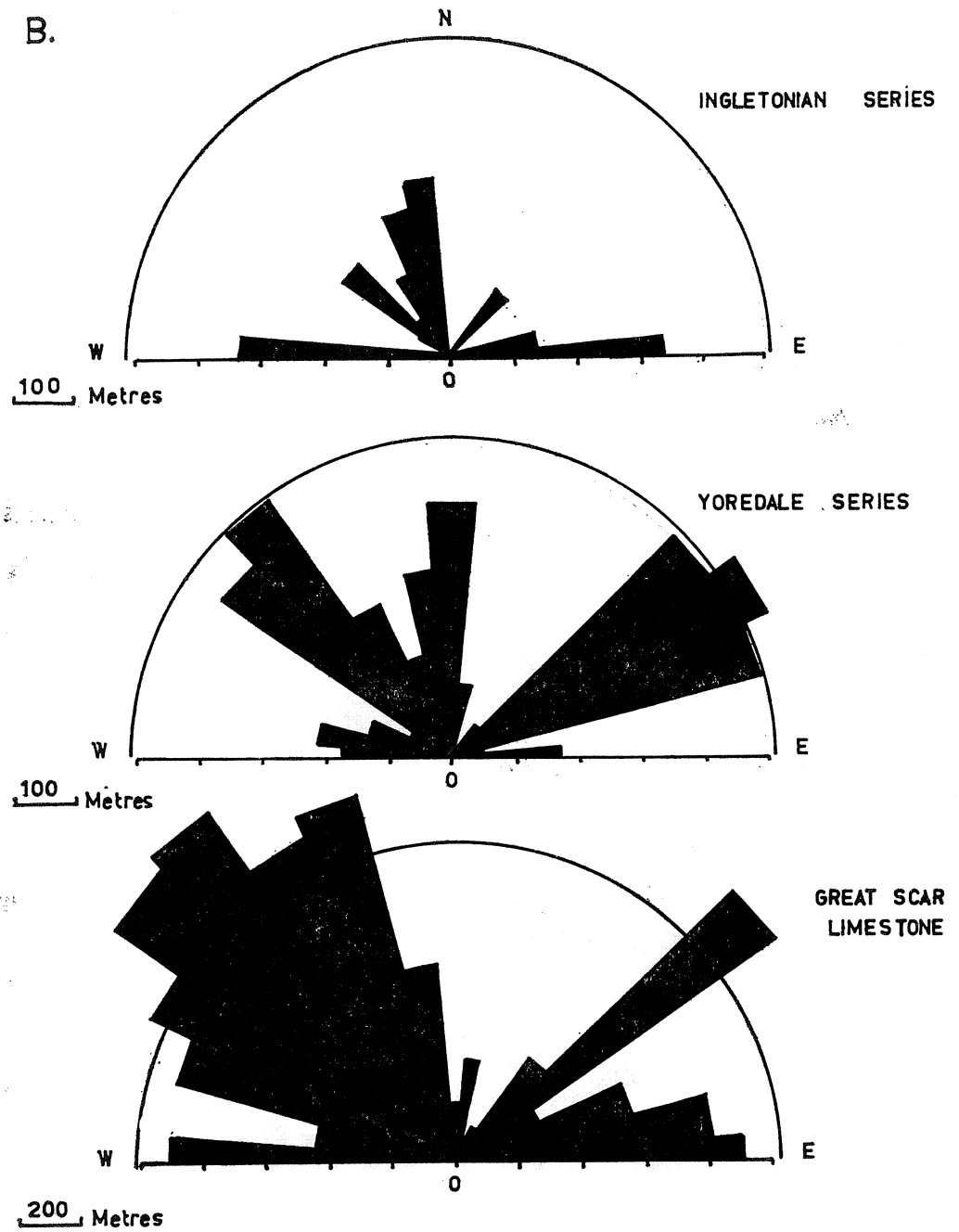

Fig. 3-B. Rose diagram of fracture trace directional density.

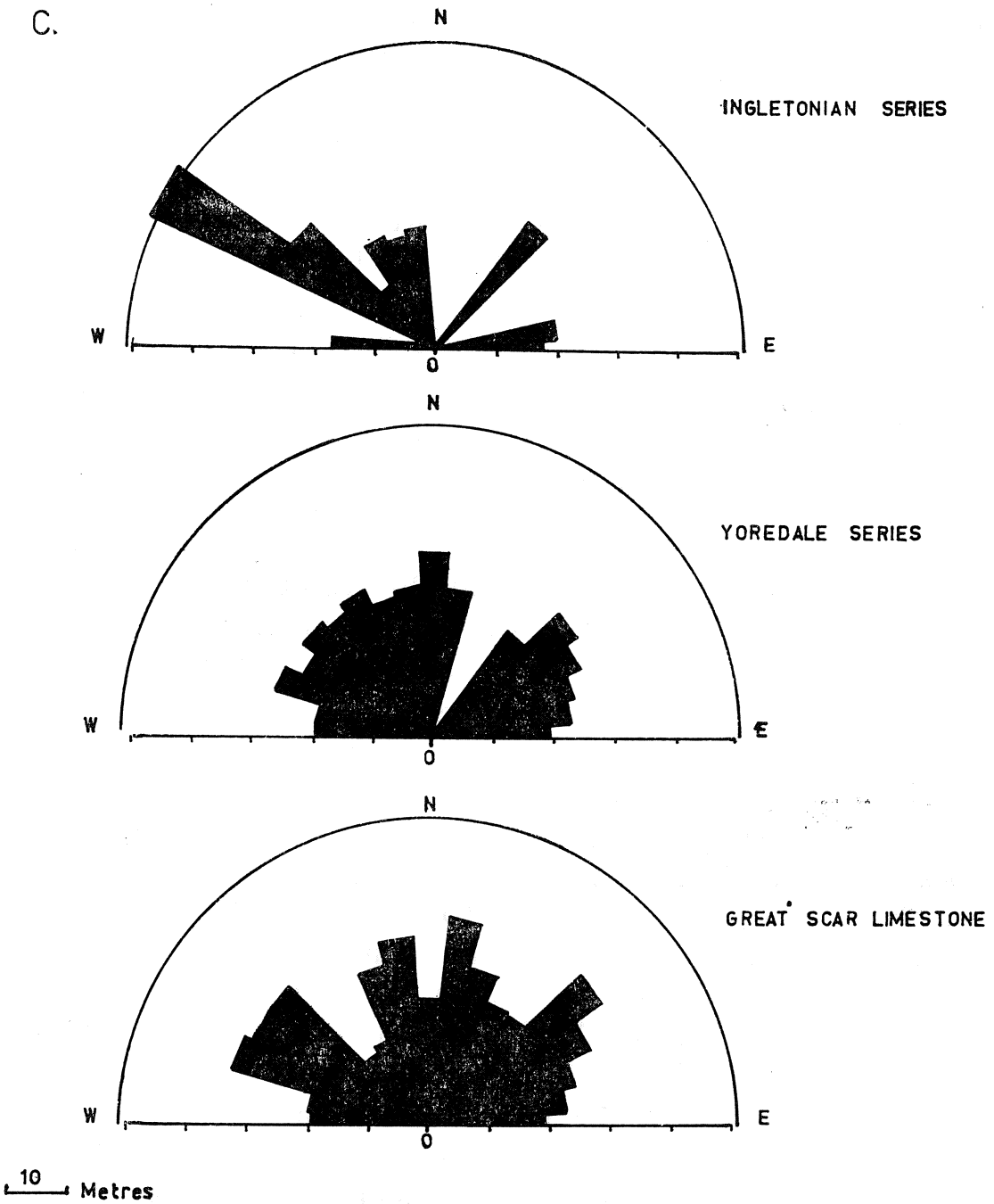

Fig. 3-C Rose diagram of fracture trace directional average length.

The average length of fractures is slightly greater in the Carboniferous limestone (Great Scar Limestone) than in the adjacent Yoredale series (Mmestone, sandstone and shale intercalations) and the Ingletonian slates and grits. Because the Great Scar Limestone is made up essentially of thick bedded limestones with thin shale bands and the competency of limestone appears to give much more pronounced fractures and longer lengths than the other two rocks. The secondary cause is the masking effects of alluvium and drift over the two rocks.

(iv) In addition to the above mentioned causes, the differences in orientation, f raquency and length of fractures in the Carboniferous Limestone displayed *on* the flanks of the Black Down pericline (at the Mendip Hills) are due to the size of the outcrop, the dip of the beds and the differenie in magnitude of stress in the flanks.

DRAINAGE CHAEAC^ERISMCS

The drainage pattern is the most consistently reliable indicator of limestones because of the general absence of large scale surface drainage, except where they are covered by impermeable soiL

The study of the drainage patterns on the photographs of the Carboniferous Limestone and adjacent shales (the Edale Shale in Derbyshire) revealed that the change of the drainage pattern coincides with the change of lithology.

The drainage patterns in each unit are quite distinct. The drainage pattern in the shale area is rather centripetal. The first order tributaries join the second order tributaries at acute angles and a group of tributaries converge to a common point. The density and frequency of drainage is great when compared with the limestone area. On the other hand, the drainage pattern in the limestone is subdendiitic or angular.

Valley shapes were also indicative to some extent in reflecting the lithologies within the Carboniferous Limestone. The change in faciès from massive limestone to limestones with breccia beds or calcite-mudstone lenses and bands, was locally reflected in the valley cross sections.

The valleys have been observed in a careful inspection of the photographs of Derbyshire. The common U shape has been converted into a deep IPs with narrow bottoms. The smooth edges of the valleys

have also been modified into sharp edges and corners. It is thought that this must be due to the presence of the individual breccia beds within the Carboniferous Limestone. Similarly massive limestones, fine grained with a characteristic vertical jointing, produced valleys having a cross sectional shape of a symmetric U wih nearly vertical sides. The thin bedded limestones with caleite-mudstones in thick lenses and bands» formed valleys having an assymetric U cross section with inclined sides.

SUPERFICIAL COVER

The superficial cover over the Carboniferous Limestone exposures has usually redused the information that can be obtained from the photographs.

This was quite serious in some areas covered with an extensive transported soil, e.g. glacial drift, blown sand. No reliable indicator could be found as the mantle carried no lithologie identification related to the Carboniferous Limestone.

This is not the same for the residual soil as it reflects to some extent the lithology underneath, e.g. medium to dark grey tone is usual for the Carboniferous Limestone areas.

CONCLUSIONS

1. Differing in grey tones was one of the identification clues in differentiating the limestones in different colours or constituent.

2i The photographs could give o clear impression of the limestone terrain by a characteristic subdued topography occupying relatively higher relief with extensive development of fracturing, but some limestone units exhibited different relief indications.

3. Some recognition features were found for various lithologies within the limestones adequately reflected on the photographs.

4. The boundaries with the adjacent rocks could be differentiated being linear.

5. Although some bare rock surfaces exhibited differing fracture patterns, the fracture trace analysis revealed that the Carboniferous Limestone has a fracture pattern not similar to other rocks nearby and one to another flank of a structure.

6. Apart from the lack of large scale surf ace drainage in the limestones» drainage patterns and the valley shapes were also indicative of limestone terrain and variations in lithologies within the limestones could be differentiated.

7. The superficial cover, especially the transported soil which carries no identification related to the limestones* usually reduced amount of information that could foe obtained from the photographs, but in the areas covered by residual soil the observations of limestones were quite satisfactory in the soil derived from the Carboniferous Limestone,

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ÖZET

ingiltere'de Karbonifer Kireçtaşlan ile kaplı alanlarda yapılmış olan bir araştırmadan bazı kısımlara yer verilmiştir.

İngiltere ve kuzeybatı Avrupa'daki Karbonifer, Alt ve Üst Kar» foonifer şeklinde iki kısma ayrılmıştır. Alt Karbonifer hemen tamamen kireçtaşlarından oluşmuştur,

İngiltere'de Karbonifer Kireçtaşlan stratigrafik sıralamada Devonien kumtaşlan ve şeylleri üzerine konkordandır ve Namurien yaş^lı bir diğer kumtaşı ve şeyi nöbetleşmesi ile örtülmüştür. Çok yerde ise bu kireçtaşlan Pra-Kambrien metamorfik karmaşığı üzerine açısal bir diskordansla gelir. Ayrıca, Triasmarnları altında görüldüğü yerler de vardır.

Sunulan çalışmanın amacı, Karbinifer Kireçtaşlarımn yüzey şekillerini hava fotoğraf lan üzerinde inceleyip araştırmak ve bu şekilde

adı *geçen* kayaların fotoğrafik görünüşleri ile fiziksel özellikleri arasında ilişkileri bulup çıkarmaktır,.

Kireçtaşlarının aflöre ettiği alanlardaki hava fotoğrafları aynalı stereoskop altında incelenmiş ve değerlendirmeler, siyah-beyaz fotoğraf kâğıtları üzerime işaretlenmiştir. Bulgular, arazi çalışmaları ve jeoloji yayınları ile karşılaşırılarak kontrol ve analiz edilmiştir.

Karbonifer Kireçtaşları, masif kireçtaşlarmdan, ince tabakalı kumtaşı ve şeyi nöbatleşmeli kireçtaşlarına, dolomitlere, dolomitîk ve resif al kireçtaşlarına, yer yer çört ve çamurtaşı merceklerinin varlı« gına kadar değişen özelliklerdik* tabakalardan oluşmuştur.

Bu özellikleri kapsayan kireçtaşlarınm röliyefi* fotoğraflar üzerinde gösterdiği renk tonları, değişik litolojileri, komşu kayalarla olan smır ilişkileri indenmiş, eklem ve fay gibi kırık izleri ve drenaj analizleri yapılmıştır.

Fotoğraflarda gri renk tonlarındaki değişimler, çeşitli renk ve bileşimdeki kireçtaşlarınm birbirlerinden ayırt edilmelerinde tanıma emareleri olmuştur. Etüd edilen bu 'nemli iklimli bölgede kireçtaşları yüksek röliyefler teşkil etmiş, karakteristik yayvan bir topografya göstermiştir. Karbonifer Kireçtaşlarmm tali sınıflanması belirli fauna zonlarma göre yapılmış olduğundan ve bu bölümler arasında de belirgen sınırlar bulunmadığından, topoğrafik değerlendirmede geçerli olmamıştır. Bunun yerine değişik tiplerdeki kireçtaşları için tanıma emareleri bulunmuştur. Komşu kayalarla olan sınırları çizgiseldir. Tekst kitaplarında söz edildiği şekilde bir geçiş zonu görülmemiştir. Kireçtaşları üzerindeki kırık izlerinin analizi göstermiştir ki; kırık örneği yakındaki diğer kaya birimlerine uymadığı gibi, bir yapının diğer kanadına da benzememiştir. Büyük çapta bir yüzey drenajı olmamasının ötesinde, drenaj örnekleri ve vadi şekilleri kireçtaşlarını tanıttığı gibi, litoloji farklarını da ayırt ettirmiştir. Karbonifer Kireçtaşları birçok alanlarda yaygın buzul tortulları île kaplanmıştır. Bu taşuımış örtü, fotoğraflardan elde edilecek bilgileri azaltmış, yerli toprakla örtülü alanlardaki gözlemler ise daha başarılı olmuştur.

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