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An electronic data processing system
for geological field and laboratory data.
The E. D. P. system Agto

by

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**GRØNLANDS GEOLOGISKE UNDERSØGELSE
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**AN ELECTRONIC DATA PROCESSING SYSTEM
FOR GEOLOGICAL FIELD AND LABORATORY DATA.
THE E. D. P. SYSTEM AGTO**

by
Steen W. Platou

**With 18 figures
(including 2 folded at back)**

1971

Abstract

An electronic data processing system has been developed to process the field and laboratory data in connection with geological teamwork mapping in a high-grade metamorphic Precambrian area around Agto in West Greenland.

The system is based on a special field note book in which standard information is recorded at each observation point in the field by numerical representations. The description of an observation consists of up to eight numerical values and as much descriptive text as required. The note book data are transferred to the computer input medium by typing the data as they are noted in the field note books. After data processing a printed note book and different types of delineation of the data are received, e. g. maps with sample numbers. Orientation data are treated in such a way that structural diagrams with selected measurements from defined sub-areas can be drawn and contoured on stereographic projections by the computer.

Laboratory data can be combined with the field data and can be subjected to the same treatment.

The system is programmed in Gier Algol 4 language and adjusted to the facilities at the computing center of Aarhus University. There are, however, no major difficulties in transferring the principles of the system to other computer systems.

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INTRODUCTION

The paper is divided in two parts. The chapters, except the last one, can be read without any knowledge about computers and programming for computers. The last chapter gives some information concerning the programme system and the computer facilities applied. The paper does not give much information about the practical use of the system. Readers interested in this can receive on request a copy of "Users manual for E. D. P. system Agto" from the author.

The amount of geological field and laboratory data is rapidly increasing, partly because the geologists try to collect more and more facts in the field and partly because the amount of laboratory facilities increases making it possible to obtain a larger amount of data concerning the samples. The increasing amount of data means that the geologist has to spend more and more time with pure administration of his data.

Teamwork becomes more and more normal in geological work. This gives, however, problems when comparing observations by individual members of a team caused by the subjectivity of the work, often making it difficult to compare results from one area to another.

The data processing system was designed for use in the Agto area in West Greenland where a university research group working under the auspices of the Geological Survey of Greenland were studying the petrology of high-grade metamorphic rocks in relation to their structural evolution. As part of the project it was decided to make a system that with the aid of a computer could handle the information expected from the structural field data and the investigation of 5000 thin sections and a few chemical analyses.

At an early stage it became clear that to do this it was necessary to standardise the field observations as it was realised that the conventional way of recording field observations was too inhomogeneous to make it possible to use them in a data processing system, as such a system requires exact sample localisation by means of coordinates and several other standard pieces of information. It was therefore necessary to develop a system for systematic recording of the field data and it was found convenient to incorporate all types of field observations into the system at once.

Although it has been found convenient to operate with a special field note book its format and practical use does not differ much from conventional note books, but the notations differ greatly. Every observation made is characterised by a set of standard information including a locality number, coordinates and rock type.

To make it possible to make these standard registrations it was necessary to apply a numerical representation system for rock types, structures and types of observations (e. g. the number '3' is the numerical representation for amphibolite). The use of numerical representations saves much space in the note books in opposition to systems working with standard schemes in which some beforehand specified items are listed as in an application form (see e. g. Haugh *et. al.* 1967) where very heavy amounts of paper are involved when much information is recorded.

It might be suggested that it is impossible to use a numerical representation system in practice, because one cannot remember the different numbers of the different objects. Anyway, no problems have occurred in using the 125 different numerical values in the Agto system. This is due to the way the system is constructed and because only about 25 of the numbers are in regular use.

An important advantage in a numerical representation system is the possibility of expanding the system during the field work without changing the note books. If, for example a new rock type is found it is given a number, which is then used in the future. During the two years of field work when the system has been used this has been important for the success of the system.

The need of a data processing system to administrate the field and laboratory data can be illustrated by the amount of data assumed to be collected in the Agto area. At least 75 000 observation points will be recorded and from these points c. 150 000 systematic registrations will be made. Approximately 15 000 samples will be collected and the investigation of these samples will give rise to c. 200 000 numerical values.

The system presented here contains many possibilities for the rationalisation of the geologist's administrative work, and it is possible to make much more advanced data processing with already existing technical equipment as, for example, a trace reader (a 'coordinate reader' delivering the coordinates in a form which can be read directly by the computer). With a trace reader it is possible to read the geological boundaries into the computer and then let the computer draw the geological maps, or maps with any specified rock types at any scale required.

Much research is being made to investigate how to read any kind of written text by means of optical methods. This means that the transference of the field data to the computer can be made very quickly.

THE GEOLOGICAL WORK IN THE AGTO AREA

The Agto area is situated between Holsteinsborg and Egedesminde in West Greenland. The area consists of high-grade amphibolite facies and granulite facies rocks in the Nagssugtoqidian fold belt (Bondesen 1966, 1968, 1969, Bondesen *et al.* 1970, Sørensen 1970). Approximately sixty different rock types are registered in the area such as amphibolites, ultramafic rocks, hypersthene gneisses, biotite gneisses and various types of metasedimentary rocks. The structural development in the area is very complex. Triple folding is normally found. At least two structural levels are present, the structures in the upper level influencing the complex structures in the lower. It is at present believed that the rocks have been through several Precambrian orogenic cycles.

The result of the mapping project will be a geological map sheet at a scale of 1 : 100 000. The mapping is mainly carried out at a scale of 1 : 20 000, each geologist having an area from *c.* 75 km² up to 300 km². Until now (1970) fifteen geologists have been involved in the work which started in the summer of 1966. The data processing system was effectively in use from the summer of 1968 although to some extent it was already in use in 1967.

THE PRINCIPLES BEHIND RECORDING OF THE FIELD DATA

After some experiments it appeared to be most effective to describe each object (an object is, e. g. a rock sample, a photograph, a measurement, etc.) registered on the observation points (localities) with a set of standard information. This means that, for example, a photograph is registered as one set of information, a so-called field data-set. If, for example more than one photograph is taken at the locality it means that more than one data-set is written. Each of the data-sets is identified by a locality number and a set of coordinates, but as all data-sets from one locality have the same locality number and coordinates it is only necessary to write down this information once for each locality.

For the description of one observation at the locality up to eight values are necessary: 1) locality number, 2) east-west coordinate, 3) north-south coordinate, 4) rock type-structure-grain size, 5) type of object and 6), 7) and 8) three values describing the object as, e. g. strike, dip and type of structural orientation measured. For rock type-structure-grain size, object and type of planar or linear orientation measured a numerical representation system is used which partly saves

space in the note book and partly makes the data processing of these recordings simple.

The eight values are written in eight columns in a specially designed field note book (fig. 1). In addition to the numerical values characterising the observation as much text as required can be written in each data-set. This means that special remarks concerning the recorded object, which any geologist would write down subjectively in his normal note book, are also involved in the system.

Several data-sets from the same locality may have the same text, which then has to be written more than once. The alternative possibility is that only one text is written for each locality independent of the number of data-sets from the locality; but as each data-set in principle should have its own text, and usually has, the system used here was preferred.

COORDINATE SYSTEMS AND AREA DIVISION

As no regional coordinate system exists on the topographic maps in Greenland it was necessary to construct a system covering the Agto area. This coordinate system (the general coordinate system) is a system of rectangular coordinates with an origin and zero point at $67^{\circ} 30'N$ and $54^{\circ} 00'W$. This means that there is a deviation between the Agto system north and the geographical north which increases with distance from the zero point. A rectangular coordinate system was preferred because it simplifies the plot of the observation points by means of the computer, but it is obvious that it would have been preferable if a coordinate system had been available for Greenland. The localisation of the observations could also have been done by means of degrees, minutes and seconds (as suggested by CoGeodata 1970), but this complicates the reading of the coordinates and the plot of the observations in an unacceptable way.

Since part of the Agto area consists of geographically isolated units (such as islands) 'local coordinate systems' were introduced for the individual areas. Such systems are linked to the general coordinate system at easily recognisable points ('reference points') such as trigonometrical points which are accurately marked on the topographic maps. The computer is programmed to convert the local systems to the general systems by means of the coordinates for the reference points.

To identify the areas mapped by the individual geologists two types of numbers are used. The total area mapped by a geologist is identified by a 'main area number'. The term 'lower degree main area number' is used to identify units within the geologist's mapping area, which have been mapped during one season's work. If the main area number, e. g. is 9, the lower degree main area numbers will then be 9.01, 9.02, 9.03 etc.

DESCRIPTION OF THE FIELD NOTE BOOK

The layout of the field note book is shown on fig. 1. The left pages contain eight columns in which the numerical values are written, the right pages are for text. The note book is used with loose sheets which means that blank pages for drawings can be inserted. Space for drawings is also available between two sets of pages as the reverse side of these pages is blank. The dimension of the note book is 21 × 19 cm.

The page for numerical values

Loc column

In the loc. column the locality number is written. To facilitate identification of localities a system with the following components in the locality number is used:

LOC	E-COOR	N-COOR	ROCK	T	I	II	K	TEXT
05818	358	201	2.295	4	26	76nw	1	Strongly altered amphibolite,
-	-	-	32.165	1	123285	0	0	small lens of graphite bearing silicate
							○	marble inside the amphibolite. dimension
								3 × 2 m
05819	349	196	28.236	4	90	52nn	1	○ normal
05820	347	204	28.236	4	26	66nw	1	○ somewhat rusty appearance
06801	258	147	2.135	4	50	46nw	1	○ heterogeneous garnet amphibolite above
								a normal partly quartzitic garnet-sill
								gneiss
06802	235	127	28.115	4	74	66nn	1	rather quartzitic. lower amphibolite
								seems to disappear in a strongly migma-
								titic ga-bi gneiss
21801	142	83	30.135	8	84	74nn	11	○ quartzitic rock together with normal
								ga-bi gneiss. medium tight simi-
								lar folds
-	-	-	-	9	60	8	5	○ Similar rather open. dip of axes
								varies much
21802	152	84	27.295	4	74	82nn	1	○ Rusty ga-qz-graphite gneiss here
								10 - 15 m broad (apparent width)
21803	164	82	27.236	4	60	64nw	1	Quartzitic garnet-sillimanite
								gneiss

Fig. 1. The field note book pages with examples of observations. The dashes on the number page are replaced by 'a' or 'b' when the note book is typed (cf. fig. 2).

Table 1. Part of the numerical representation system used for rock types, structures in the rocks and for grain sizes.

'Code' is the numerical values used in the note book. 'Printing layout' is the way the text is printed by the computer.

Table 1 a Numerical representations for some rock types

Rock type	Code	Printing layout
<u>Amphibolite group</u>		
Amphibolite group unspecified	1	AMPHIBOLITE GROUP
Garnet amphibolite	2	GA-AMPHIBOLITE
Amphibolite	3	AMPHIBOLITE
Garnet pyribolite	4	GA-PYRIBOLITE
Pyribolite	5	PYRIBOLITE
<u>Ultramafic group</u>		
Gabbro anorthosite	10	GABBRO ANORTHO.
Ultramafic rock	11	ULTRAMAFITE

Table 1 b Numerical representations for some of the structures

Structure	Code	Printing layout
Homogeneous	0.09	HOMOGENEOUS
Homogeneous foliated	0.10	HOMO.FOLIAT.
Heterogeneous foliated	0.11	HET.FOLIATE.
Finebanded heterogeneous	0.12	FINEBAN.HET.

Table 1 c Numerical representations for some of the grain sizes

Grain size	Code	Printing layout
Fine-grained	0.004	FINE
Fine to medium-grained	0.005	FIME
Medium-grained	0.006	MEDI

the two first ciphers give the date (e. g. 05 for the fifth), the next cipher indicates the number of the month (e. g. 7 for July), and the final two ciphers for the number of the locality.

When several localities are very close to each other, the geologist can be forced to keep them under one locality number (e. g. because of location difficulties or map scale). In this case it is possible by means of sub-locality numbers, to keep these localities separated in the system. The sublocality numbers are given with two ciphers after the point in the locality number, e. g. 05705.02 is sub-locality number two at locality 05705.

This can be applied to a simple field sketch, e. g. covering a small island, which then is given one locality number, but on which there can be up to 99 sub-localities.

E-coor and N-coor columns

In these two columns are written the easting and northing coordinates for the locality. The coordinates are seldom written in the field, but mostly at a later occasion. The localities are generally marked on the maps or the aerial photographs during the field work. This is done by making a small hole in the map with a needle and the locality number is then written on the back of the map.

Rock column

In the rock column is written the numerical representation of the rock type, the structures of the rock, and the grain size. This is made by one number e. g. 2.095. The cipher before the point (viz. 2) gives the rock type. The first two ciphers after the point give the structure and the last cipher the grain size. 2.095 then means: garnet amphibolite homogeneous, medium to fine grained. Zeros can be inserted for any of the three components in the number. Part of the numerical representation system used is found in table 1. At present (1970) 59 rock types, 35 structure types, and 8 grain sizes are incorporated in the system.

T column

The letter T stands for the type of object. In this column is written the numerical representation of the object described in the data-set. The numerical values used for the objects are listed in table 2. The object number can be used to separate different variants of the object. For example it is possible to separate orientations belonging to different phases of folding by adding a value after the point in the object number, e. g. 4.1 could mean a general planar structure formed during the first deformation period.

A distinction is made between general structures and local structures. Local measurements are, for example measurements within a mesoscopic fold on one locality, while general measurements are the orientation used for mapping purposes.

Among other possibilities with the object number it should be mentioned that it

Table 2. List of the objects recorded in the Agto area with their numerical representations.

'Structure' stands for one of the structures listed in table 3.

Object	Code	Printing layout
Sample number	1	SAMPLES or SAMPLE NO.
Photograph number	2	PHOTOS or PHOTO NO.
Drawing number	3	DRAWINGS or DRAWING NO.
General planar structure	4	"structure" + GEN or GEN. PLANAR
General linear structure	5	"structure" + GEN or GEN. LINEAR
Geiger counter measurement	6	GEIGER or GEIGER MEA.
Rock type description	7	ROCK DESCRIP.
Local planar structure	8	"structure" + LOC. or LOC. PLANAR
Local linear structure	9	"structure" + LOC. or LOC. LINEAR

is possible to distinguish between samples collected for different purposes, e. g. 1.1 could be samples meant for thin sections, 1.2 could be samples for chemical analyses, etc. It is then possible to obtain lists of the sample numbers collected for specific purposes by means of the computer.

No limitation in the number of object types exists. Object number 10 could, for example, mean height above sea level and 11 could mean a locality description. Further, geophysical measurements in addition to the geiger counter measurements can be recorded in the note book. For example a gravimetric measurement can be recorded with the instrument reading in I column, time in II column and height in K column.

I column

In the I column is written a value characterising the object. The value can for example be: a sample number, a photograph number, a drawing number, a strike of planar structures, a direction of dip for linear structures or a background geiger counter measurement. The numeration system selected by the geologist for the photographs and drawings can be used to separate different types of these objects. One type of photograph can be numerated with numbers from 0 to 1000, another

type with numbers from 1000 to 10000, etc. This separation could also be done by adding a decimal figure to the object number, or the object number could be used to separate different types of film or pictures taken with different types of filters or objectives. These examples with the photographs are only used to illustrate the flexibility of the system.

II column

In the II column is written, if possible, a second value characterising the object. This value can be the amount of dip and direction of dip for planar structures (e. g. 45 nw), dip of linear structures or rock values in geiger counter measurements.

Table 3. List of the types of planar and linear structures used in the Agto area with their numerical representations.

Structure	Code	Printing layout
Foliation	1	FOLIATION
Axial surface foliation	2	AX. SUR. FOLI
Layering	3	LAYERING
Banding	4	BANDING
Measured fold axis	5	MEASU. AXIS
Constructed fold axis	6	CON. AXIS
Lineation	7	LINEATION
Discordant planar orientation	10	DISC. ORIEN.
Axial surface	11	AX. SURFACE

K column

The numerical representation for the kind of planar or linear structure measured is written in the K column. The values used in the area are listed in table 3.

The text page

On the text page can be written as much text as required for each data-set. The text is written in continuation of the line with the numerical values for the data-set. There are some limitations as some characters (a character is typed any time a key is depressed on the typewriter) do not occur in the computer. The maximum number of characters to one data-set is set at 500. This amount of text is rarely exceeded, and if this is the case the text is divided between two or more data-sets.

05818,358,201,2.295,4,26,76,nw,1,

strongly altered amphibolite,

a32.165,1,123285,0,0,

small lens of graphite bearing silicate

marble inside the amphibolite.dimension 3x2 m,

05819,349,196,28.236,4,90,52,nn,1,

normal,

05820,347,204,28.236,4,26,66,nw,1,

somewhat rusty appearance,

06801,258,147,2.135,4,50,46,nw,1,

heterogeneous garnet amphibolite above a normal

partly quartzitic garnet-sill gneiss,

06802,235,127,28.115,4,74,66,nn,1,

rather quartzitic.lower amphibolite seems to disappear

in a strongly migmatitic ga-bi gneiss,

21801,142,83,30.135,8,84,74,nn,11,

quartzitic rock together with normal ga-bi gneiss,

medium tight similar folds,

b9,60,8,5,

similar rather open. dip of axes varies much,

21802,152,84,27.295,4,74,82,nn,1,

rusty ga-qz-graphite gneiss here 10-15 m broad(apparent width),

21803,164,82,27.236,4,60,64,nw,1,

quartzitic garnet-sillimanite gneiss,

Fig. 2. Typing of the field data shown on fig. 1.

PUNCHING AND CORRECTION OF THE FIELD DATA

The data in the field note books are transferred to the computer input media, which is a paper tape in which holes are punched representing the values and text in the note books. This is done on a flexowriter which is like a normal electric typewriter. The typing of the data is very simple, as they are typed as they stand in the note book; the only additions made are commas to separate the values (compare fig. 1 and fig. 2).

When more than one data-set is available from one locality it is only necessary to type the locality number and coordinates once, as these three values can be replaced by the letter: a. If also the rock type is common to more than one data-set from the locality the first four values can be replaced by the letter: b.

Correction of the typed data

When the field data have been transferred to the paper tape it is necessary to make an error control as the computer can only accept the data when the format is correct, i. e. the number of values in the data-set and the relations between the numerical values and the text are correct. The data are checked by means of a computer programme which, as a result of the checking, delivers a list with the data-set numbers (first column) and the locality number (second column) and for data-sets in which errors occur the type of error is written (third column); an error list could be:

45	23607.00	
46	23608.00	type 4
47	23609.01	
48	23609.02	type 2
49	23610.00	
50	50612.00 ₁₀ ³	type 1

Here type 4 means that the number of values in the data-set is wrong, type 2 that something is wrong with the rock type code, and type 1 that the locality number probably is wrong. The geologist receives a printed copy of the data together with the error list, and because of the simple structure of the data it is rather easy to find the errors and to have them corrected by means of a computer programme. Although the computer after the corrections may be able to accept the data this does not mean that the data are correct as discrepancies between the field data and the data stored in the computer may occur. The geologist therefore also receives a printed copy of his data without the text for comparison with the original note book values; the wrong data-sets can then easily be corrected. It is of course of

great importance that the data-sets are correct, and the present system seems to make this possible with a minimum amount of work.

Recalculation of the data

When the data have been corrected they are recalculated for 'technical' reasons; this does not involve any work by the geologist. During the recalculation the general coordinates are calculated from the local coordinates and the strike for planar structures is recalculated to direction of dip.

STANDARD TREATMENT OF THE FIELD DATA

Field observation type-out

The printed note book received from the computer consists of:

- a: list with all field observations (e. g. fig. 3)
- b: list with coordinates for the localities (e. g. fig. 4)
- c: list of samples (e. g. fig. 4)
- d: list of drawings
- e: list of photographs
- f: list of planar structures (e. g. fig. 5)
- g: list of linear structures
- h: list of rock type descriptions
- i: list of geiger counter measurements

The list with all field observations (fig. 3) gives all information from the field note book except the coordinates, which are given in the list of coordinates (fig. 4). The lists c to i correspond with a list of each of the recorded objects in the present version of the system. The lists d to i give locality number, coordinates, the numerical values and the text (e.g. fig. 5). The list of samples also gives the rock type (fig. 4).

Maps

Together with the above mentioned lists the following types of maps are delivered:

- a: map with the locality numbers (fig. 6 & 17)
- b: map with sample numbers
- c: map with drawing numbers
- d: map with photograph numbers
- e: map with geiger counter measurement anomalies
- f: map with the general planar structures (fig. 18)
- g: map with the general linear structures

IN_A.M.E.: S.W.PLATOU Y.E.A.R.: 1969 A.R.E.A. N.O.: 9.13 S.C.A.L.L.E. F.O.R. C.O.O.R.: 1:

LOCALITY	ROCK TYPE	STRUCTURE	GRAIN SAMPLE	PHOTO	DRAW	STRI	DIP	DIR	DIP	TYPE
5818.00	GA-AMPHIBOLITE	MINERALISED	FINE	-	-	26 76	NW	-	-	FOLIATION GEN.
5818.00	SILICATE MARBLE	HETEROGENE.	FINE	123285	-	-	-	-	-	STRONGLY ALTERED AMPHIBOLITE , SMALL LENS OF GRAPHITE BEARING SILICATE MARBLE INSIDE THE AMPHIBOLITE.DIMENSION 3x2 M ,
5819.00	GRA-GA-SILL-GN	MIGMATITIC	MEDI	-	-	90 52	N	-	-	FOLIATION GEN.
5820.00	GRA-GA-SILL-GN	MIGMATITIC	MEDI	-	-	26 66	NW	-	-	NORMAL , FOLIATION GEN.
6801.00	GA-AMPHIBOLITE	FINEBANDED	FINE	-	-	50 46	NW	-	-	SOMEWHAT RUSTY APPEARANCE , FOLIATION GEN.
6802.00	GRA-GA-SILL-GN	HETE.FOLIATED	FINE	-	-	74 66	N	-	-	HETEROGENEOUS GARNET AMPHIBOLITE ABOVE A NORMAL PARTLY QUARTZITIC GARNET-SILL GNEISS , FOLIATION GEN.
21801.00	QUARTZITE	FINEBAND.HETE.	FINE	-	-	84 74	N	-	-	RATHER QUARTZITIC. LOWER AMPHIBOLITE SEEMS TO DISAPPEAR IN A STRONGLY MIGMATITIC GA-BI GNEISS , AXIAL SURFACE LOC
21801.00	GA-SILL-GNEISS	MIGMATITIC	MEDI	-	-	60 8				QUARTZITIC ROCK TOGETHER WITH NORMAL GA-BI GNEISS. MEDIUM TIGHT SIMILAR FOLDS , MEASURED AXIS LOC
										SIMILAR RATHER OPEN. DIP OF AXES VARIES MUCH ,

E.D.P.SYSTEM AGTO LIST OF PLANAR STRUCTURES

Fig. 3. List of field observations with all information from the note book (cf. figs. 1 and 2) except the coordinates.

NAME: S.W.PLATOU YEAR: 1969 AREA NO: 9.13 SCALE FOR COLOR: 1:

LOCALITY	E-COOR	N-COOR	ROCK TYPE	STRUCTURE	GRAIN	SAMPLE NO	TEXT
5802.00	319.0	165.0	AMPHIBOLITE	HOMO.FOLIA.	FINE	123283	HOMOGENEOUS AMPHIBOLITE FROM CENTR RT ,
5817.00	372.0	211.0	MYLONITE	HETE.FOLIA.	MECO	123284	PROBABLY A RECRYSTALISED MYLONITE
5818.00	358.0	201.0	SILICATE MARBLE	HETEROGENE.	FINE	123285	SMALL LENS OF GRAPHITE BEARING SIL MARBLE INSIDE THE AMPHIBOLITE.DIME 3x2 M ,
21802.00	152.0	84.0	MINE.SKARN	MINERALISED	FINE	123286	META-AMPHIBOLITIC ROCK(SKARN-AMPHI E) ,
21802.00	152.0	84.0	GRA.SULPHI.ROCK	MINERALISED	FINE	123287	GRAPHITE-SULPHIDE MINERALISED ROCK
21802.00	152.0	84.0	GRA.SULPHI.ROCK	MINERALISED	FINE	123288	GRAPHITE-SULPHIDE MINERALISED ROCK THE TYPE OCCUPYING C. 50 O/O OF TH UME.RATHER LARGE PARASITIC FOLDS A AL ,

E.D.P. SYSTEM AGTO LIST OF SAMPLES

NAME: S.W.PLATOU YEAR: 1969 AREA NO: 9.13 SCALE FOR COLOR: 1:

LOCALITY	LOCAL COORDINATES		GENERAL COORDINATES	
	E-COOR	N-COOR	E-COOR	N-COOR
5801.00	322.0	174.0	868.0	811.0
5802.00	319.0	165.0	865.0	802.0
5803.00	331.0	179.0	877.0	816.0
5804.00	341.0	181.0	887.0	818.0
5805.00	341.0	186.0	887.0	823.0
5806.00	334.0	186.0	880.0	823.0
5807.00	326.0	191.0	872.0	828.0
5808.00	323.0	197.0	869.0	834.0
5809.00	303.0	185.0	849.0	822.0
5810.00	313.0	181.0	859.0	818.0

E.D.P. SYSTEM AGTO LIST OF COORDINATES

Fig. 4. Above: List of samples with all note book information about the samples. The list of drawings and photographs is similar to the list of samples. Below: List of coordinates with local and general coordinates for each locality.

INAME: S.W.PLATOU YEAR: 1969 AREA_NO: 9.13 SCALE_FLOOR_COLOR: 1:

LOCALITY	E-COOR	N-COOR	STRIKE	DIP	TYPE	TEXT
5801.00	322.0	174.0	50 66 NW	FOLIATION	GEN.	NORMAL MIGMATITIC AND SMALL-FOLDED A FEW QUARTZITIC LAYERS
5802.00	319.0	165.0	54 66 NW	FOLIATION	GEN.	NORMAL, WITH QUARTZITIC LENSES AND CA. 10 CM THICK BANDS
5803.00	331.0	179.0	50 62 NW	FOLIATION	GFN.	NORMAL WITH QUARTZITIC LAYERS
5804.00	341.0	181.0	46 70 NW	RANDING	GEN.	RATHER HOMOGENEOUS BANDED AMPHIBOLITE. LOCALLY A FEW GARNETS. LARGE PLAGIOCLASE PEGMATITE AT THE SOUTHERN CONTACT
5805.00	341.0	186.0	78 70 N	RANDING	GEN.	TURNING ROUND HERE -NICE RATHER OPEN SIMILAR FOLDS ON THE RIDGE
5806.00	334.0	186.0	90 64 N	RANDING	GEN.	ONLY FAINTLY BANDED
5807.00	326.0	191.0	74 64 N	FOLIATION	GEN.	ALTERED GA-SILL GNEISS .A RATHER THIN (0.5-1 M) SKARN-AMPHIBOLITE. ON THE SOUTHERN SIDE OF THIS A 30x10 M PYRRHOTITE LENS OF NORMAL TYPE
5808.00	323.0	197.0	90 76 N	FOLIATION	GEN.	MIXTURE BETWEEN HY-GNEISS AND BIOTITE GNEISS FACIES ABOVE GA-SILL GNEISS ABOVE A AMPHIBOLITE
5809.00	303.0	185.0	68 72 NW	FOLIATION	GEN.	VERY HETEROGENEOUS LIGHT GARNET AMPHIBOLITE
5810.00	313.0	181.0	64 68 NW	FOLIATION	GEN.	SKARN-AMPHIBOLITE RATHER BROAD HERE DUE TO INTENSE FOLDING
5811.00	299.0	174.0	38 82 NW	FOLIATION	GEN.	THE SMALL SKARN-AMPHIBOLITE IS INTENSELY FOLDED AND OCCUR ABOVE THE GRAPHITE BEARING GNEISS AS PROTECTION

E.D.P.SYSTEM AGTO LIST OF PLANAR STRUCTURES

Fig. 5. List of measured planar orientations. GEN means a general measurement. The list of linear structures is similar to the list of planar structures.

The maps are drawn on a drawing machine (x-y plotter) connected with the computer and are delivered at a scale of 1:20 000 corresponding to the normal mapping scale. The alternative to producing the maps on the plotter fig. 17 is the possibility of printing the maps on A-4 format paper, as shown on fig. 6. An example of a map with structural orientations is shown as fig. 18.



Fig. 6. Printed locality map, the + and 0 indicate the coordinate position of the localities. The printing of the numbers takes place when enough space is available between two locality marks or after the last mark on a line. When numbers are connected with '-' it means that the localities (e.g. 22604-17610) lie so close that they are represented at the same locality mark. The top line gives information for identification, and the second line the local and general coordinates for the corners of the map (marked with +).

One disadvantage exists with the maps drawn on the plotter, i.e. when localities lie close to each other the numbers are drawn on top of each other (see fig. 17). If this happens it is possible to have the maps drawn at a larger scale. On the maps the localities are marked with different symbols for the different years of mapping. These symbols are listed below the maps (see fig. 17).

Lists

Besides the above mentioned note book lists with planar and linear structures, lists of these structures can be obtained with the local and general measurements separated. These lists are delivered to make the further treatment of the structural data easier (see below).

FURTHER POSSIBILITIES IN THE TREATMENT OF THE FIELD DATA

The standard treatment described in the preceding chapter is the background for further treatment of the field data. In this treatment data can be included from other areas in the Agto region.

The further treatment is partly based on the so-called 'subarea' concept. A subarea is either a rectangular area of any size defined by grid lines or a single locality. A subarea can be composed of as many rectangular areas as required to compensate for the fact that subareas required for analysis are not always rectangular in shape. In practice the use of the rectangular shape has not presented any special problems.

Maps

Maps of the types described in the preceding chapter can be obtained at any scale required and covering any part of the area. It is possible to insert certain limitations on the values to be plotted on the maps, e. g. only sample numbers of a specified rock type, or only lineations, etc.

If a locality has been divided into sublocalities and the sublocalities have been given separate coordinates it is possible to have information from the sublocalities plotted on separate maps for each locality at a scale corresponding to the scale of the field sketch. This is an important property in the system because it makes it possible to administrate detailed investigations in a simple way.

NAME : S.W.PLATOU YEAR: 1969 SUBAREA NO : 15
 DATA FROM AREA NO : 9.13
 COORDINATES FOR THE CORNERS : 0, 600 600, 600 546, 1156 1146, 1156
 0, 0 600, 0 546, 556 1146, 556

YEAR	LOCALITY	E-COOR	N-COOR	SAMPLES	ROCK TYPE	STRUCTURE	GRAIN SIZE
1969.09	5802	319	246	123283	AMPHIROLITE	HOMO.FOLIATED	FINE
1969.09	5817	372	292	123284	MYLONITE	HETE.FOLIATED	MECO
1969.09	5818	358	282	123285	SILICATE MARBLE	HETEROGENE.	FINE
1969.09	21802	152	165	123319	MINE.SKARN	MINERALISED	FINE
1969.09	21802	152	165	123320	GRA.SULPHI.ROCK	MINERALISED	FINE
1969.09	21802	152	165	123321	GRA.SULPHI.ROCK	MINERALISED	FINE
1969.09	21803	164	170	123322	MINE.SKARN	IMPREGNA.TYPE	FINE
1969.09	21804	179	179	123323	SULPHIDE ORE	PSEUDOCGL.	MECO
1969.09	22802	133	161	123324	GA-AMPHIBOLITE	HETE.FOLIATED	FINE
1969.09	22802	133	161	123325	GA-AMPHIBOLITE	HETE.FOLIATED	FINE
1969.09	22803	141	166	123326	SKARN	HETEROGENE.	FINE
1969.09	22803	141	166	123327	GRA.SULPHI.ROCK	HETE.FOLIATED	MEDI
1969.09	22812	155	181	123228	ULTRAMAFIC	HOMOGENE.	MECO
1969.09	22812	155	181	123329	ULTRAMAFIC	HOMOGENE.	MECO
1969.09	23801	146	177	123330	QUARTZITE	HOMOGENE.	FINE
1969.09	23801	146	177	123331	SKARN	HETEROGENE.	MEDI
1969.09	23801	146	177	123333	SILICATE MARBLE	HETEROGENE.	MEDI
1969.09	23801	146	177	123332	SILICATE MARBLE	HETEROGENE.	MEDI
1969.09	23804	122	161	123334	GRA.SULPHI.ROCK	HETE.FOLIATED	FINE

Fig. 7. A list of sample numbers with rock type. The coordinates for the corners of the subarea (No. 15) are given as local and general coordinates. Each sample is identified by year of mapping (1969), main area number (.09), locality number and coordinates (either local, as here, or general). Similar lists can be made for other objects, such as a specified rock type.

Lists

It is possible to have lists with any specified object, rock type, or structure, for example a list with all note book information on lineations measured in amphibolites.

Other types of lists only give relevant information about the objects, e.g. lists with sample numbers or photograph numbers for the different rock types (e.g. fig. 7). Generally lists can be delivered by specification of limits on any of the numerical values recorded in the data-set.

Structural analyses

Besides the possibility of being able to draw maps with structural orientations, it is possible to sort out the measurements within individual subareas or from a single locality or sublocality. The sorted out structural orientations can either be printed in a list (fig. 8) or plotted on stereographic projections, or where there are sufficient measurements contoured stereographic projections can be obtained. These projections can be delivered with any of the types of planar and linear structures recorded and a distinction between the local and the general orientations can be made. On fig. 9 are shown examples of stereographic projections with the measurements plotted together with a contoured projection for the same measurements. In connection with the contoured diagrams a printed diagram is delivered with the percentage of the measurements at a number of calculation points (e.g. fig. 10).

The best fitting great circle pole (Kalsbeek 1966) or the best fitting small circle (after the method described by Ramsay 1967) can further be calculated for the measurements from a subarea, a locality or a sublocality, and lists with the deviation between the measurements and the calculated great or small circles can be delivered. Further it is possible to have all great or small circle poles from a selected number of subareas, localities or sublocalities plotted in one diagram; to have a new best fitting great or small circle calculated; and to have printed the deviations between the old poles and the new circles. In the individual projections the great circles themselves can be plotted and the confidence ellipses for the great circle poles drawn (see fig. 9).

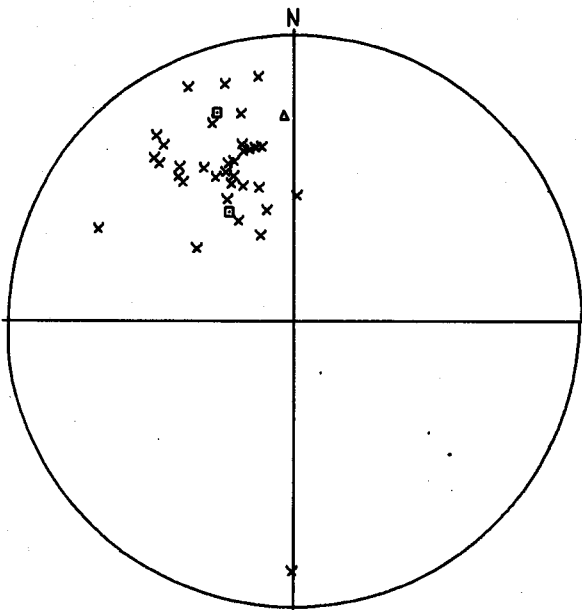
Contouring of stereographic projections

The possibilities for administration and depicting of the structural measurement are very extensive. The computer programme used for the structural analysis will later be published. Since contoured stereographic projections are a possibility made avail-

YEAR	LOCALITY	E-COOR	N-COOR	GENERAL PLANAR	TYPE	ROCK TYPE
SUBAREA NO : 1						
DATA FROM AREA NO : 9.13						
COORDINATES FOR THE CORNERS :						
		0,	250	250,	250	546,
		0,	0	250,	0	546,
						882
						796,
						882
						632
						796,
						632
1969.09	6802.00	235	132	74 66 N	FOLIATION	GRA-GA-SILL-GN.
1969.09	21801.00	142	88	92 48 N	FOLIATION	GA-SILL-GNEISS
1969.09	21802.00	152	89	74 82 N	FOLIATION	GA-SILL-GNEISS
1969.09	21803.00	164	94	60 64 NW	FOLIATION	GA-SILL-GNEISS
1969.09	21804.00	179	103	52 66 NW	FOLIATION	GA-SILL-GNEISS
1969.09	22801.00	128	78	38 46 NW	FOLIATION	QUARTZITE
1969.09	22802.00	133	85	68 62 NW	FOLIATION	GA-SILL-GNEISS
1969.09	22803.00	141	90	70 62 N	FOLIATION	GRA.SULPHI.ROCK
1969.09	22804.00	126	82	50 74 NW	FOLIATION	GRA.SULPHI.ROCK
1969.09	22805.00	114	67	77 44 N	FOLIATION	GRA.SULPHI.ROCK
1969.09	22806.00	112	66	76 64 N	FOLIATION	GRA.SULPHI.ROCK
1969.09	22807.00	98	60	68 74 NW	FOLIATION	GRA.SULPHI.ROCK
1969.09	22808.00	100	72	62 52 NW	FOLIATION	GA-AMPHIBOLITE
1969.09	22809.00	120	78	62 44 NW	FOLIATION	GA-AMPHIBOLITE
1969.09	22810.00	152	94	62 60 NW	FOLIATION	GA-AMPHIBOLITE
1969.09	22811.00	146	96	26 74 NW	FOLIATION	GRA.SULPHI.ROCK
1969.09	22812.00	155	105	88 72 N	BANDING	ULTRAMAFIC
1969.09	22813.00	156	110	74 64 N	FOLIATION	GA-SILL-GNEISS
1969.09	22814.00	160	115	90 82 S	FOLIATION	QUARTZITE
1969.09	22815.00	169	123	68 58 NW	FOLIATION	BI-HY-GNEISS
1969.09	22816.00	182	132	50 72 NW	FOLIATION	BI-HY-GNEISS
1969.09	22817.00	199	131	76 52 N	FOLIATION	GA-AMPHIBOLITE

Fig. 8. List of planar structures, similar to the list on fig. 7. Lists of this type can be made with any of the types of planar and linear structures measured and with data from as many areas as required.

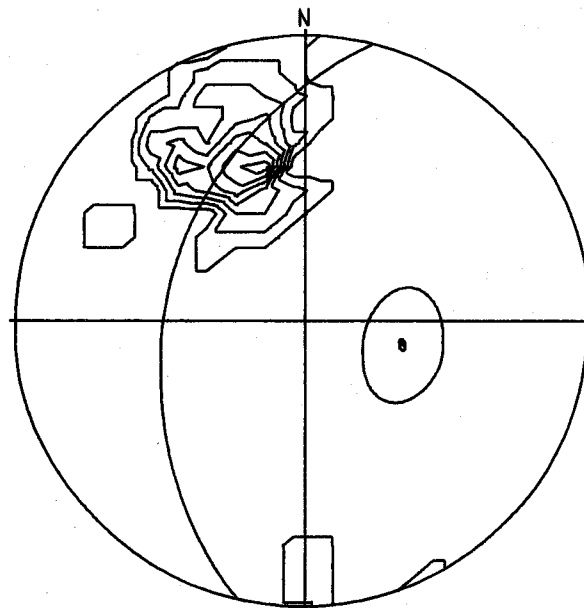
SUBAREA NO : 1
N = 38 TYPE : 1



UPPER HEMISPHERE

X - FOLIATION + - AX.SURF.FOL. □ - LAYERING Δ - BANDING ⊗ - DISC.ORIEN. ◇ - AXIAL PLANE
 ⊙ - MEA.AXIS * - CALC.AXIS ▣ - LINEATION
 ● - GREAT CIRCLE POLE ⊖ - SMALL CIRCLE POLE

SUBAREA NO : 1
N = 38 EQUIDIST. : 4.0 % TYPE : 1



UPPER HEMISPHERE

Fig.9. *Left*: Plotted stereographic projection including the measurements listed on fig. 8. *Right*: Contoured stereographic projection, with the pole and great circle for the best fitting great circle and the confidence ellipse based on the values for the standard deviation on strike and dip for the great circle pole (cf. (u, v) in fig. 10).

able by the use of computers in contrast to contoured equal area projection, which can be made by hand, the principles will be described briefly.

The projection shown on fig. 10 contains a number of points (printing points), to the right of which are found numerical values. These values represent the number of measurements in the neighbourhood of each calculation point (a calculation point is the projection of the printing points upon the upper or lower hemisphere, (see fig. 11)). The number of calculation points can be changed by changing the number of printing points either by varying the diameter of the projection or by changing the distance between the printing points. In practice it is possible to have projections with 372, 830 and 2544 printing points. The projection with 372 printing points has been selected as standard projection as it is satisfactory for most purposes.

To facilitate the contouring one measurement has to influence the numerical value of more than one printing point, i.e. in each calculation point is counted the number of measurement within a circle covering a defined area of the hemisphere. An area of one percent of the hemisphere has been selected as this gives the most

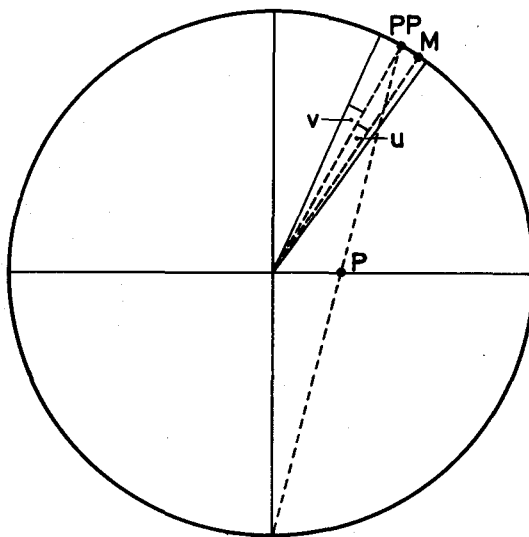


Fig. 11. The principle behind the construction of the printed and contoured stereographic projections (cf. figs. 9 and 10). P is a printing point (the points on fig. 10). The calculation point PP is the projection of P upon the upper (or lower) hemisphere. When the angle u between a measurement M and PP is smaller than the fixed angle v the measurement will be represented as the value printed at P. In the standard projection (fig. 10) the angle v is 8 degrees, which means that measurements within the nearest 1 percent of the hemisphere area around PP are counted at P. The contoured projections are based on the calculated P values, which means that more detailed curves can be obtained by using more printing points.

SECTION NO: 123126.1 ROCK: 14.116 NAME: SP YEAR: 68 AREA: 9.06

MINERAL	CODE	EST.VOL.%	COUNTS	MINERAL	CODE	EST.VOL.%	COUNTS
Quartz	14.1	20	103 *	Carbonate	09.4	0	0
Perthite	17.			antiperthite	18.1	65	306 *
Plagioclase	19.						
Biotite	23.204	10	63				
Hornblende	27.						
Hypersthene	29.3	0	9				
Ore	42.3	0	0				
Apatite	13.3	0	0				
Diopside	30.						
Sillimanite	36.						
Garnet	37.						
Altered	41.4	1	8				
Others	44.						

Type: x n in first count: 2Count I: 451 Count I corr: 390 Count II: 912 Count II corr: 912n = 4 I 34 I 32 I 38 I 36 I I I I I I I I I ISample description: typical hypersthene gneiss with brown weathering surface. Hypersthene visible. Very irregular Foliation. Small leuco veins <Texture: Heterogeneous granoblastic <Structure: Weakly developed parallel orientation in biotite grains a few kink folded biotite grains <Alterations: hypersthene ca. 50 percent altered to mica and Calcite <Other remarks: The plagioclase are strongly antiperthitic. The Plagioclase shows complex twins and is somewhat zonary,

Occurrence code for the minerals: .1 = main primary mineral .2 = main accessory mineral .3 = accessory mineral .4 = alteration product.

SP/70/6

satisfactory results. By changing the angle ν (see fig. 11) it is possible to change the size of the calculation area; in the programme it is possible to use from 0.7 to 1.6 percent of the hemisphere area as counting area. The 1 percent area means that all measurements within a circle with a radius of 8 degrees are counted at each calculation point, which is reasonable with respect to the measuring error for the structural orientations.

THE RECORDING SYSTEM FOR THE LABORATORY DATA

Principles behind the system

The investigation of the samples in the laboratory gives five groups of data: 1) mineralogical data, 2) point-counting data, 3) chemical data, 4) petro-physical data, and 5) sample description. As each of these groups only implies registration of relatively little information, it is possible to use standard schemes with fixed space for the different values and texts.

The standard scheme used for mineralogy and point-counting data is shown as fig. 12. The schemes are used for registration of values which are systematically collected by all the geologists involved. This implies, for example that for the mineralogy scheme it is not possible to register items such as 2V angles, refractive index, pleochronism etc. These items can only be recorded in the text. The difference between information written in the text and information written in the systematic part of the schemes is that the systematic information can be used for sorting the different items, which is not possible with the information written in the text.

Fig. 12. Standard scheme for registration of point-counting and mineralogical data obtained by laboratory investigation of thin sections. Only the most common minerals are found on the scheme; other mineral names and codes can be written in the blank boxes. In the example a double point-counting has been made i.e. quartz, antiperthite + others have been counted as one group (451 counts) and biotite, hypersthene, ore, apatite, carbonate, altered + others have been counted as another group (912 counts). This method gives a higher precision in the determination of the accessory minerals. A normal single point-counting is also allowed in the system.

The mineralogy and point-counting scheme

This scheme (fig. 12) is described in some detail as it gives the principles behind the laboratory data handling part of the system.

On the top line of the scheme is written some standard information concerning the thin section. In the thin section number subnumeration can be done by means of the first cipher after the point, and the photographic work done on the total thin section can be registered as a further two ciphers adjacent to the subnumber.

Rock type is given in the same numerical representation system as is used in the field note book. In practice the rock type may be redefined after the examination of the thin section; these problems are discussed later.

Below the heading there are columns for information about the minerals in the thin section. Each mineral is identified by a numerical code found in the CODE column. Adjacent to the code number is written, as the first cipher after the point, a numerical value denoting the occurrence of the mineral in the thin section; for example, 1 means a main primary mineral. Photographic work concerning the minerals can be registered by means of a further two ciphers in the number (see biotite on fig. 12). The other data recorded for each mineral observed in the thin section are an estimate of the volume percentage of the mineral and, if any, the number of points counted by means of a point-counter.

Below the mineral columns is space for the total number of counts and the non-correlated number of independent counts according to the method described by Kalsbeek (1969).

In the line below the total count information is written on the anorthite content in the plagioclase, and the rest of the scheme is used for texts describing the thin section.

TREATMENT OF THE LABORATORY DATA

Initial treatment

The data on the schemes are typed on the flexowriter approximately as they are noted in the schemes. Then the data are tested for format errors and an error list is made as for the field observation data.

When the data are correct they are, by means of the computer, combined with the corresponding field observation data; at the same time the point-count figures are recalculated into volume percentage and the standard deviation on the values are calculated either by means of the method of Van der Plas & Tobi (1965) or by the modified method of Kalsbeek (1969). The average anorthite content in the plagioclase and the standard deviation for the content are also calculated.

The other types of laboratory data are also combined with the field data, but no initial calculation on the data is performed.

Standard treatment of the laboratory data

A number of tables and lists with the basic results of the laboratory investigation are received from the computer in the same way as the field data.

```

_S_A_M_P_L_L_E_ _N_O_      : 123126.1   _L_O_C_A_L_L_I_T_Y_ _N_O_ : 24608.00
_R_O_C_K_ _I_I_N_ _F_I_E_L_D_      : HY-GNEISS           HETE.FOLIAT.    MEDI
_R_O_C_K_ _I_I_N_ _T_H_I_N_ _S_E_C_T_I_O_N_ : BI-HY-GNEISS       HETE.FOLIAT.    FIME
_C_O_O_R_D_I_N_A_T_E_S_ : 85.0 E. 302.0 N.    1992.2 E.2192.8 N.
_N_A_M_E_ _O_F_ _C_O_L_L_E_C_T_O_R_ : S.W.PLATOU
_Y_E_A_R_ : 1968      _A_R_E_A_ _N_O_ : 9.06
_F_I_E_L_D_ _N_O_T_E_S_ :
      NORMAL HYPERSTHENE GNEISS WITH A FEW DARK BANDS
      AND PRACTICALLY NO AMPHIBOLITE LENSES ,

      MINERALS          EST VOL 0/0  VOL 0/0  2xS          PHOTOGRAPHS
M.PR. QUARTZ           20          23       3.6
M.PR. ANTIPTERTHITE   65          68       4.8
M.ACC. BIOTITE        10          7        1.3          DIAS W. 1 NIC.
ACC. HYPERSTHENE      0           1        0.4
ACC. ORE               0           0        0.2
ACC. APATITE          0           0        0.0
ALT. CARBONATE        0           0        0.0
ALT. ALTERED          1           1        0.4

TOTAL COUNT 1 : 451      CORR.COUNT : 390      P.P.C. : 1.15
TOTAL COUNT 2 : 912      CORR.COUNT : 912      P.P.C. : 1.00

AN-CONTENT IN PLAGIOCLASE: 36 2xS: 3.4  N = 4

_S_A_M_P_L_L_E_ _D_E_S_C_R_I_P_T_I_O_N_ :
      TYPICAL HYPERSTHENE GNEISS WITH BROWN WEATHERING SURFACE.
      HYPERSTHENE VISIBLE. VERY IRREGULAR FOLIATION. SMALL LEUCO
      VEINS <
_T_H_I_N_ _S_E_C_T_I_O_N_ _N_O_T_E_S_ - :

TEXTURES : HETEROGENEOUS GRANOBLASTIC <
STRUCTURES : WEAKLY DEVELOPED PARALLEL ORIENTATION IN BIOTITE GRAINS.
            A FEW KINK FOLDED BIOTITE GRAINS <
ALTERATIONS: HYPERSTHENE CA. 50 PERCENT ALTERED TO MICA AND CALCITE <
OTHER NOTES: THE PLAGIOCLASE ARE STRONGLY ANTIPTERTHITIC. THE PLA.SHOW
            COMPLEX TWINS AND IS SOMEWHAT ZONAR ,

```

Fig. 13. Example of page delivered for each point-counted thin section. Besides the laboratory data (cf. fig. 12) the field data concerning the sample are given. P.P.C. (points per count) are calculated by use of the 'non-correlated' number of counts according to the method described by Kalsbeek (1969). 2 x S is the double standard deviation on the different values, N=the number of anorthite content determinations.

SAMPLE NO.=>	90003.0	90004.0	90006.0	90008.0	90010.0	90105.0	90106.0	90109.1
CARBONATE	-	-	-	X	-	-	-	-
APATITE	-	X	-	X	-	-	-	-
QUARTZ	-	X	-	X	-	-	-	-
PLAGIOCLASE	X	X	X	X	X	X	X	X
BIOTITE	X	-	-	X	X	-	-	-
HORNBLLENDE	X	X	X	-	X	X	X	X
HYPERSTHENE	X	X	X	X	X	X	X	X
DIOPSIDE	-	-	X	-	X	X	X	X
ALTERED	-	-	-	-	X	X	X	X
ORE	X	X	X	X	-	X	X	-
MUSCOVITE	-	-	-	X	-	-	-	-

SAMPLE NO.=>	90003.0	90004.0	90006.0	90008.0	90010.0	90105.0	90106.0	90109.1
CARBONATE	-	-	-	0 S: 0.0	-	-	-	-
APATITE	-	1 S: 0.4	-	0 S: 0.3	-	-	-	-
QUARTZ	-	22 S: 3.6	-	29 S: 2.9	-	-	-	-
PLAGIOCLASE	5 S: 1.5	67 S: 4.0	36 S: 3.5	49 S: 3.3	31 S: 3.4	21 S: 2.8	41 S: 3.4	44 S: 3.5
BIOTITE	7 S: 1.7	-	-	17 S: 3.1	1 S: 0.6	-	-	-
HORNBLLENDE	37 S: 3.3	2 S: 0.8	57 S: 3.6	-	59 S: 3.6	70 S: 3.0	42 S: 3.4	45 S: 3.5
HYPERSTHENE	49 S: 3.4	6 S: 1.3	5 S: 1.6	2 S: 1.0	4 S: 1.5	6 S: 1.6	3 S: 1.2	5 S: 1.7
DIOPSIDE	-	-	2 S: 0.9	-	5 S: 1.5	1 S: 0.5	11 S: 2.2	6 S: 1.6
ALTERED	-	-	-	-	0 S: 0.0	0 S: 0.0	0 S: 0.0	0 S: 0.0
ORE	2 S: 1.0	2 S: 0.8	0 S: 0.3	-	2 S: 0.9	3 S: 1.2	-	-
MUSCOVITE	-	-	-	3 S: 1.5	-	-	-	-

Fig. 14. Tables with the qualitative and quantitative mineralogy. Such tables can be printed for specific rock types or rock types containing a specified mineralogy. Another type of table contains only the volume percentages for up to six minerals and gives the average content of the individual minerals.

Schemes and tables

One page for each sample is delivered either with the mineralogical results, the point-counting results, or the chemical data. The petro-physical data are delivered in lists. An example of such a page with the results from a point-counting are shown in fig. 13.

Tables with the results from up to eight samples are made. These tables only show the components which are present in at least one of the samples in the table. Two examples are shown in fig. 14.

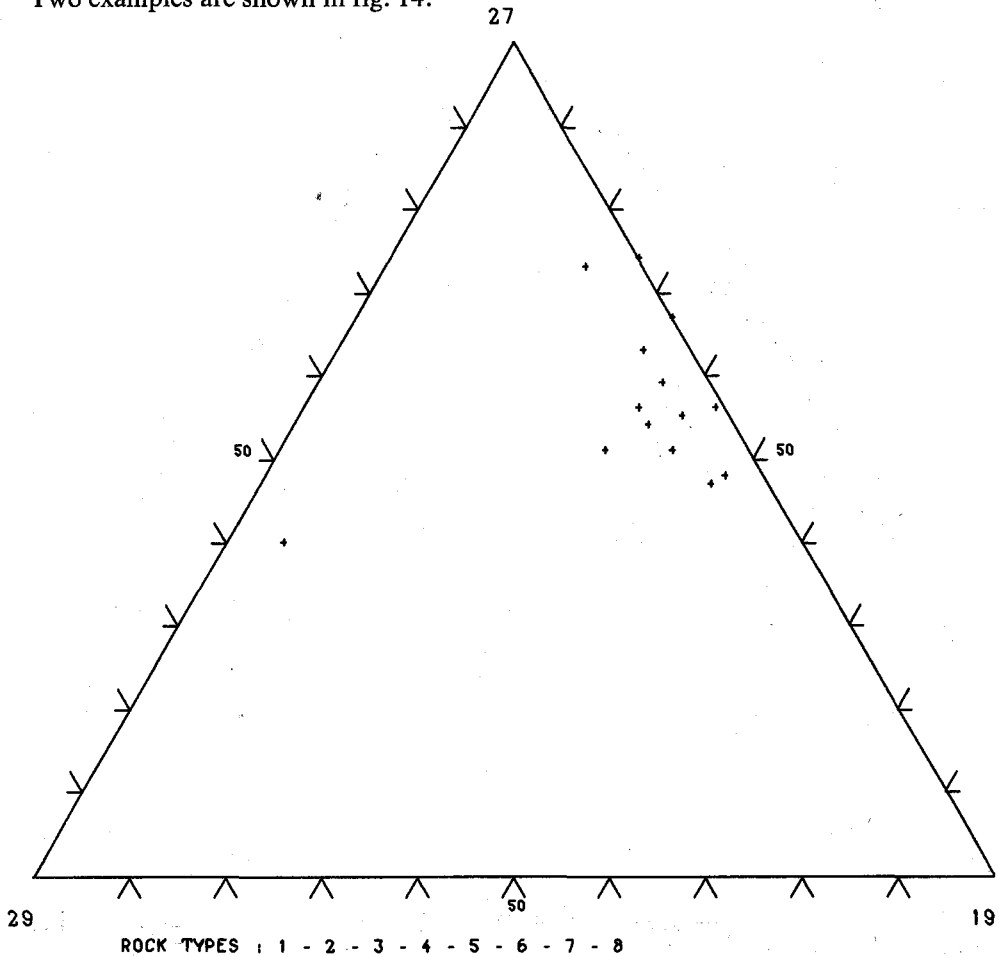


Fig. 15. Triangular diagram with the content of the minerals 29, 19 and 27 (hypersthene, plagioclase and hornblende) for the rock types 1-2-3-4 etc. (amphibolites). Similar two component diagrams can be made. Both types of diagram can be made with the average content of the minerals in as many rock types as required in one diagram. Further the average content of minerals in one rock type from different subareas can be plotted in one diagram, with the subarea numbers s besides each $+$ in the diagram.

Maps

Maps with sample numbers showing the localities of the investigated samples are delivered together with the tables and schemes.

Further possibilities in the treatment of laboratory data

As with the field data a great number of possibilities exist for additional treatment of the data. It is possible to sort out information on the basis of limitations in the numerical values for each of the systematically registered items. These possibilities can be illustrated by some examples. It is possible to sort out the content of any mineral in a specified rock type and further it is possible to perform a statistical treatment of the values. Values can be illustrated graphically in different ways, for example in a triangular diagram (fig. 15). It is possible to sort out samples with a specified mineral paragenesis and further the distribution of the different parageneses can be illustrated on maps at any scale and covering any part of the map sheet, i.e. it is possible for the computer to produce metamorphic facies maps.

The examples mentioned are only a few of the possibilities which exist in the system. The possibilities are, as far as possible, coordinated. When for example point-counting data from some samples have been listed it is also possible to obtain easily other information concerning the same samples.

It should be pointed out that a data-processing system such as the one presented in this paper never will be finished. New possibilities for treatment of data will continually be involved, and there will always be possibilities for incorporation of new types of data.

The treatment described here is an attempt to make a usable compilation of the data in such a way that they are represented in a well arranged manner. The system does not at present contain possibilities for the testing of geological models; however, the compilation should make it possible to set up such models.

REMARKS CONCERNING THE GENERAL USE OF THE SYSTEM

Although the system has been developed in connection with the mapping on the Agto map sheet, it can be stated that the system can be used directly in any geological mapping project. This is because of the independence between the text corresponding to the numerical representation system and the numbers, which means that the programme system is independent of the area in which the mapping

takes place and which numerical representation system is used. For example, it can be decided in one area that the value '2' represents a garnet amphibolite, but in another area the value '2' may represent a sandstone. The programme system is then made in such a way that the geologist in each area only has, by means of a number, to tell the computer which numerical system he wants to use and then the text corresponding to this number is used in the output from the computer.

A fundamental problem in using a data processing system, of the type described here, is to make the numerical representation system. This is not difficult, but much discussion will arise when deciding, for example, which rock types should be involved and which petrological limits should be allowed for the rock types. The nomenclature problem is important because the data processing system is designed to do administrative work in such a way that it is possible to compare data collected by different geologists, and in this connection the rock type is important as it occurs in all the field and laboratory data-sets.

During the field work the geologist maps different rock units each of which is identified by a field name, e.g. migmatitic biotite gneiss. When samples of the rock unit are examined in the laboratory it normally becomes possible to characterise the rock unit with a rock type name, for example according to the nomenclature proposed by Streckeisen (1967). The migmatitic biotite gneiss can then be recorded as e.g. granitic-migmatitic biotite gneiss. Sooner or later during the mapping, on a regional scale, it becomes possible in the system to record that the rock unit belongs to a specific stratigraphic unit, e.g. the Nagssugtoqidian. The migmatitic biotite gneiss can now be recorded as: Nagssugtoqidian-granitic-migmatitic biotite gneiss, and the computer can be asked for the data-sets containing any combination of these three names, for example if a list of all Nagssugtoqidian data-sets are wanted the data-sets will be delivered together with all other data-sets belonging to the Nagssugtoqidian.

It is unfortunately not so simple in practice, for example one geologist can use the field name biotite gneiss *sensu stricto* for the rock unit, another geologist can use the name migmatitic biotite gneiss and a third the name biotite gneiss unspecified, which means that in the field data the same rock unit can be recorded under several names, while the rock unit on the final map will have a common name, e.g. biotite gneiss. To overcome this problem it seems reasonable to introduce a fourth name into the recordings i.e. a common field name, which is inserted, by means of a computer programme, in the data-sets when agreement has been obtained between the geologists involved. It could be suggested that the common field name could be built into the numerical representation system for the rock types, but in practice this can give problems, for example because the discrepancy becomes too large between the field name used by the geologist and the common field name. An actual example from the Agto area can be used as an illustration. A rock unit mapped as granitic biotite gneiss was found to be a hypersthene gneiss when the thin sections were examined, but because the rock unit

is not the same as the other hypersthene gneisses in the area it can not be redefined as hypersthene gneiss; on the other hand the name biotite gneiss cannot be kept as the rock then will be put in the same group as the true biotite gneisses in the area. One solution seems to be the possibility of giving the biotite gneiss a common field name such as: white hypersthene gneiss. Another solution is to use the name white hypersthene gneiss as the original field name, but the problem is then that the geologist during the field work has been accustomed to the use of the original name (granitic biotite gneiss). Further, from the view of the compiler of a map sheet, it is an advantage to have the common field names incorporated in the recordings because the compiler then does not need to go back to the records of the individual geologists to see what the geologist has meant with a certain rock name.

By using these four names for the rock units it seems possible to overcome most of the problems due to the ambiguity in the use of the field names. Similar problems, as mentioned for the rock types, are present for the other names used as e.g. the rock structures and the type of planar or linear structures measured, but the problems in connection with these names do not seem to be as serious as the problems with the rock names. The problems arise partly because the individual geologist during the mapping seldom has the possibility to ask other geologists whether a rock unit in his area corresponds to a rock unit mapped by some of the other geologists, and partly because the geologist is limited in his ability to separate

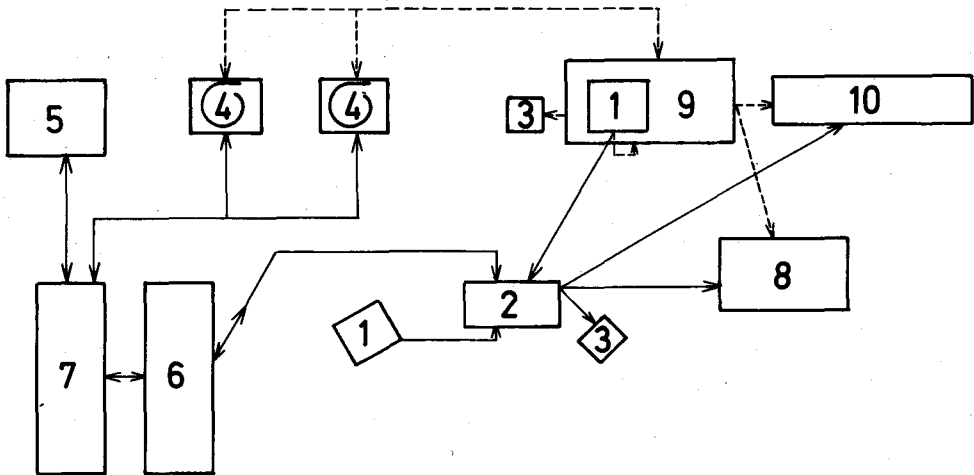


Fig. 16. Plan of the computer facilities applied: 1: paper tape reader (RC-2000), 2: control board with typewriter, 3: paper tape puncher (Facit 150), 4: magnetic tape station, 5: disk drive unit (Control Data 9433), 6: computing unit (Gier), 8: lineprinter, 9: converter unit (RC-3000) for off line printing and drawing, 10: x-y plotter (Calcomp 563). Broken lines indicate units connected with the converter and solid lines units connected with the computing unit. The arrows indicate the possible ways for information transport.

the different rock types in the field. The last relation is clearly reflected in the use of the field names. In 11.487 field observations from the Agto area, the four most used rock type names are on average used in 70 percent of the field data-sets, although on average 25 of the available rock type names have been used. This is partly because only a few rock types dominate an area, and partly because the geologist needs some years' experience with the system before he is able to fully utilise its possibilities.

THE PRINCIPLES BEHIND THE SYSTEM IN THE COMPUTER PROGRAMMING

This chapter gives a description of some of the basic features in the programming system. A complete description of the programmes is outside the scope of this paper, but details may be obtained from the author on request.

Computer facilities applied

In fig. 16 is shown a plan of the installations of the computing center at the University of Aarhus. These facilities seem to be what, at least, are necessary if the present data processing system should function effectively.

The computer system is a GIER system (Andersen *et. al.* 1966), but in the spring of 1971 a CDC 6400 computer system will become available at the computing center. Some basic information about the GIER computer can be given here. One cell (or one word) consists of 42 parts. The storage capacity available is:

Store	Words	Access time for 1 variable
Core store I	1024	less than 0.1 millisecond
Core store II	4096	0.3-0.7 millisecond
Disc store	1.2×10^6	27-125 milliseconds*)

*) for 600 words transferred to core store II.

The input medium used is a paper tape reader (eight channel punch tape) with a reading capacity of 2000 characters per second. The output media are: paper tape puncher, lineprinter and an x-y plotter.

Off line drawing on the plotter and off line printing is possible from magnetic tape by means of a converter unit.

The first programmes were written in Gier Algol 3 (Naur 1964 a & b), but a Gier Algol 4 (Naur 1967) compiler became available early in the development of the system, and the programmes are therefore written in this language.

Handling of the field data

Initial treatment

Although the typing of the data in the field note books is simple the punched field data contain from two to six percent wrong data-sets. About one half of these errors are format errors in the data-sets, i.e. errors meaning that the computer cannot accept the data-set, therefore the first step in the treatment is to find and correct these errors. The punched data are tested for the format errors and are corrected by means of a computer programme. When the computer can accept the data they are recalculated. The recalculation programme inserts the general coordinates, replaces the 'a' and 'b' in the data-sets with the locality numbers, coordinates and rock type, and the strike of planar structures are recalculated into directions of dip. The original field data-sets are transferred by the recalculation to so-called 'standard field data-sets', which are kept permanently on punched paper tape.

The next step is the transference of the standard field data-sets to magnetic tape. This is done in two formats i.e. as the standard field data-sets are and as so-called 'compressed field data-sets'. One standard field data-set consists of 120 words, while one compressed field data-set consists of 8 words (numbers) because the text has been removed. The two formats have been introduced because in most of the treatment the text is without interest and therefore the sorting in connection with the treatment of the data can be made faster by using the compressed field data-sets.

When the data have been transferred to magnetic tape, a printed table with the compressed field data-sets is produced and the data-sets stored in the computer can be compared with the original records in the note book. Wrong data-sets are then replaced by correct ones by means of a computer programme.

Administration of the data

As the programmes can use data from an arbitrary number of lower degree main areas, it was necessary to develop a system which could make this possible in a fast and effective manner.

On the magnetic tapes the data are stored in files each containing the data from one main area; the standard field data-sets and the compressed field data-sets are stored as separate files. In the first step the main area data-sets are transferred to a disc-area and stored here under a file name, but as the disc-area contains data from all the lower degree main areas in the main area, it is necessary to have information available about where on the disc-area the data-sets from the different lower degree main areas are stored. Besides the information about where on the disc-area the data are found, some other information about the lower degree main areas should be available e.g. the name of the geologist, the year of mapping, the scale for the coordinates and the number of data-sets. This information is stored in a separate disc-area which contains the information about all the lower degree main areas on the map sheet. The contents of this disc-area are transferred into an array in the

programmes during the running of the programmes. By changing the information in the disc-area it is possible in a simple way to change the area information according to which mapping project is treated by the programmes.

If data from several map sheets were involved in the system it would probably be necessary with an administration programme to tell the user which lower degree main area occurs within an actual map sheet, eventually within a specified part of the map sheet. This programme could function in such a way that the user only asks for data by means of coordinates. The administration programme then finds out which lower degree main areas occur within the wanted area and inserts the descriptions in the disc-area, and tells the user which magnetic tapes should be available for the computer.

Handling of the texts corresponding to the numerical values.

The texts corresponding to the numerical values used in the field note books are also stored permanently on a disc-area and treated in the same way as the content of the disc-area with the lower degree main area information i.e. the content of the disc-area can be changed in a simple way, and further new texts can easily be inserted. To make handling simpler, a text unit consists of 15 characters stored in three words, and the texts are stored in 7 groups, which are:

- | | |
|---|----------------------------|
| 1) rock types | 2) structures in the rocks |
| 3) grain sizes | 4) mineral names |
| 5) type of planar and linear structures | 6) object names |
| 7) names of geologists | |

Short description of some of the programmes

The programmes handling the standard field data-sets have a simple structure and problems in connection with these programmes are mainly concerned with layout.

The programmes handling the compressed field data-sets are more complicated as the main part of the data processing is done with these programmes. The main problem is the sorting of the data as it is on this point that computing time can be saved. The first step is an initial sorting where the relevant values for the actual programme are subtracted, for example the programme for plot of locality numbers only requires the locality number and the coordinates. Further a first sorting by means of coordinates takes place during the initial sorting.

When maps, with locality or other numbers, and maps with structural orientations, are plotted a square net with 200×200 mm sides is initially drawn covering the map area. The values which have to be drawn within each of these squares are then sorted out by means of coordinates from the data obtained by the initial sorting, and are drawn as they are found. In cases where several numbers belong to the same locality they are drawn ahead of each other, but in case two localities lie close to each other the values may be drawn on top of each other. This problem cannot easily be solved if the computing time is to be kept on a reasonable

level, and it is of greater advantage to have every value plotted adjacent to the locality mark instead of as is done on the printer produced maps (cf. figs. 6 and 17) where the numbers often are printed far away from the locality mark. In practice the overdrawing problem is negligible.

On the printed maps the numbers are sorted out line for line and arranged in the correct order on the line, and correction for overlap is made. This is a rather complicated process, but the computing time for these maps is considerably smaller than for the plotter produced maps. The printed maps were mainly made at an early stage in the development of the system because at that time no digital plotter was available.

The listing programmes operate principally as the programmes producing the maps, but instead of the sorting within each map square the data from the initial sorting are sorted by means of the subarea coordinates.

The programme for structural analysis has a very complicated structure and it will be described in a separate publication. It should be mentioned that other data processing systems (e.g. Adler *et. al.* 1968a, Adler *et. al.* 1968b, Spencer & Claibagh 1967) treating orientation data use equal area projections. But as it is angles which are measured, the stereographic projection presented here is more satisfactory. It can be mentioned that the planar orientations are projected from the upper hemisphere and the linear orientations from the lower hemisphere; by this plots are obtained where the measurements are placed in such a way that a correct visual impression of the direction and amount of dip is obtained directly.

Handling of the laboratory data

The laboratory data are combined with the corresponding field data by comparing the sample numbers. This requires that the sample numbers in the field data-sets are correct. This procedure results in 'standard laboratory data-sets', for example 'standard chemical data-sets'.

The principles in the treatment of the laboratory data are much like the principles described for the field data and no special problems are met with.

An important link between the different types of laboratory data and the field data is the recording of the facts that have been investigated on the samples. This information, such as whether a thin section is available of a sample, is stored on a separate disc-area, and this information can be used in all relevant programmes for sorting purposes; for example one can have lists with note book information concerning samples of a specific rock type from which thin sections have been made. The note book information is of course available at each thin section description data-set, but the advantage is that the field data handling programmes can be used directly, which means that it is not necessary to write special programmes for the laboratory data, such as programmes which can produce maps with sample numbers of a specific rock type from which thin sections are available.

Use of the programmes on other computers

Unfortunately the programme system has to a high degree been adjusted to the available computer facilities, which in practice means that the programmes cannot be used directly in other computer systems, not even in other Gier computers. When the CDC 6400 computer comes into operation the programmes will be rewritten, which means they will be more generally transferable to other computer systems. The main problem with the GIER computer is the limited core store capacity, which has meant complicated programming.

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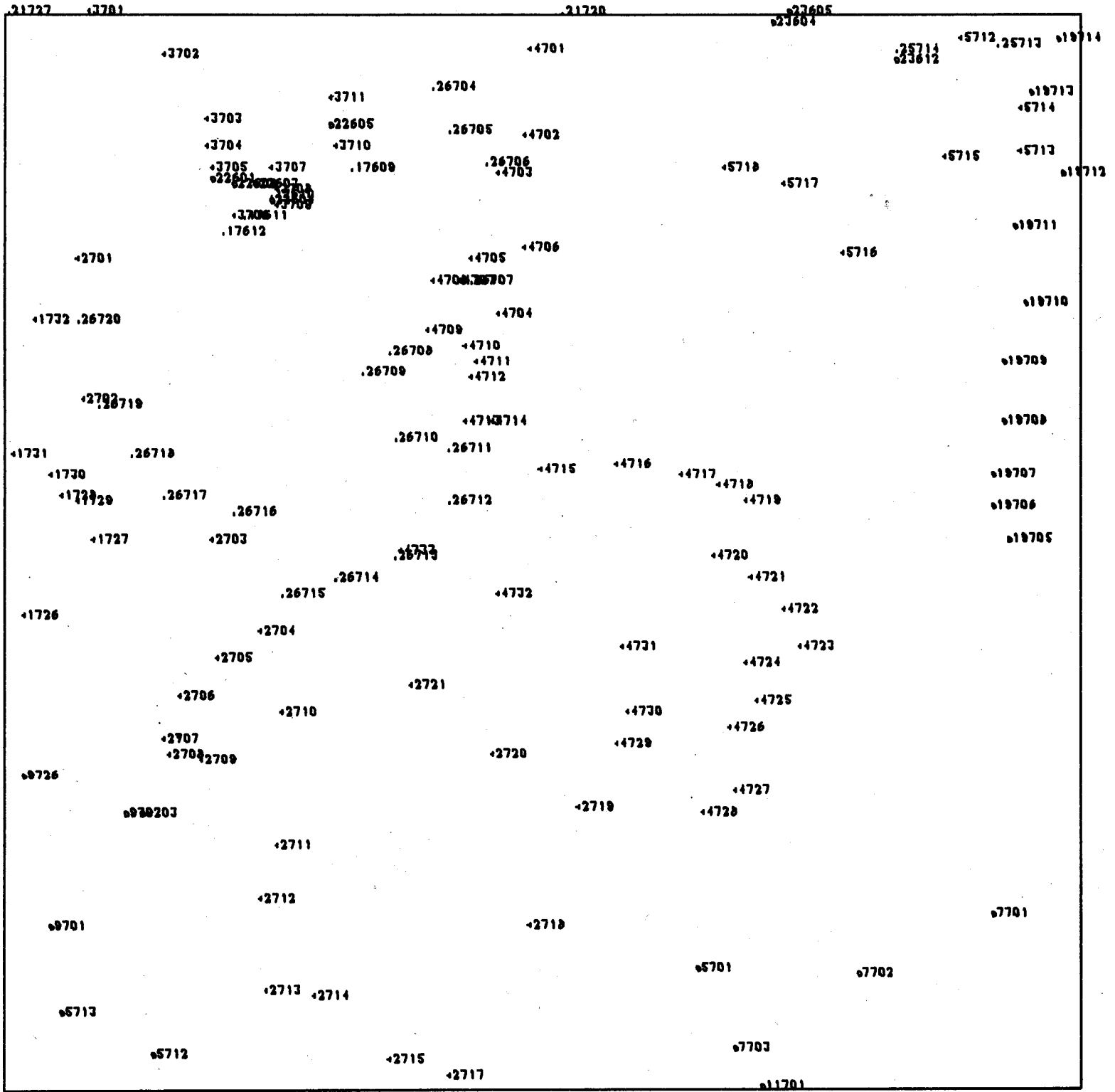
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300 EAST 700 NORTH



AGTO LOCALITY MAP

SCALE 1 : 20000

YEAR 1966 1967 1968 1969 1971

SYMBOL , | + o x

DATA FROM AREA NO : 901 902 905 908 909 912

Fig. 17. Locality map drawn on plotter (cf. fig. 6).

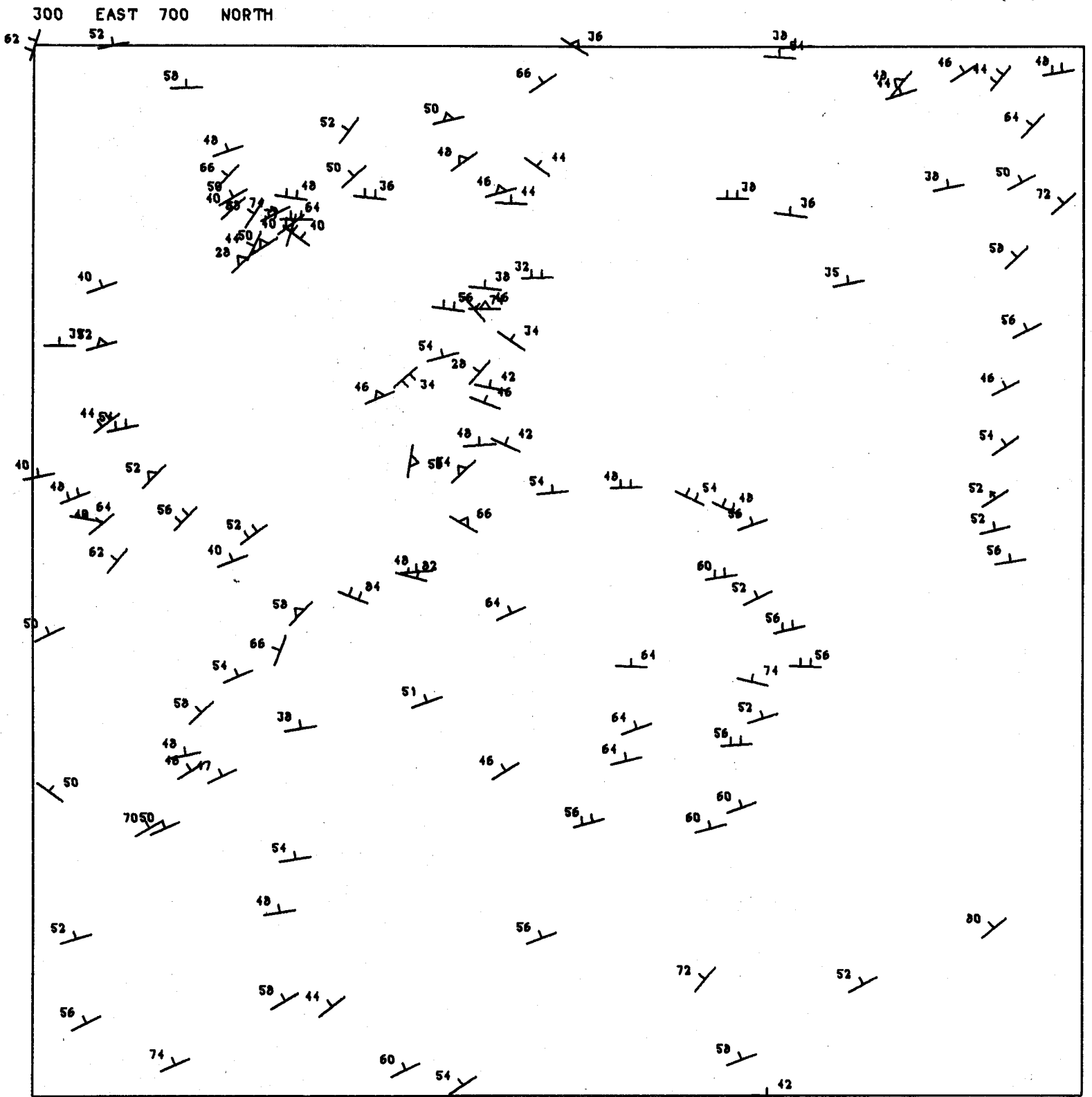


Fig. 18. Plotter drawn map with general planar structures. Only one orientation is drawn for each locality. If a locality has been divided into several sublocalities, similar maps (in e.g. a scale of 1: 100) can be made with one orientation from each sublocality.