Göpfritz Area, Austria

General Information and Summary of Geological and Geotechnical Investigations
as per September 1967

also to be considered as

Explanatory Notes

for the

Synoptic Map of Geology and Geotechnics

1 : 10.000

Übersichtsdarstellung des Gebietes von

Göpfritz, Niederösterreich

Stand September 1967

zugleich

Erläuterungen

zur

Geologisch-Geotechnischen Grundlagenkarte

1 : 10.000

von Göpfritz in Niederösterreich

Gesamtbearbeitung: Geologische Bundesanstalt, Wien

WIEN 1967
Eigentümer, Herausgeber und Verleger: Geologische Bundesanstalt, Wien 1030, Rasumofskygasse 23
Druck: Österreichische Staatsdruckerei

Contents

Summary

The ultimate operational efficiency and success in the field of high energy physics of any synchotron will only be influenced remotely by the conditions of the underground.

In the present state of forethought and planning, however, the stability of the rock-underground is considered a reliability asset of primary importance with far-reaching consequences for construction and technical development.

With a view to these considerations, early in 1965 the Göpfritz area was proposed by Austria as a possible site—mainly on account of the hardrock underground, the flat topography, the absence of practically any seismic activity, and also because no settlements would eventually have to be removed from there.

Of course, the sum total of all non-geological requirements, as for instance climate, accessibility, planning of settlements, attractive social conditions (as outlined in detail by CERN) will also be factors of importance as far as the ultimate decision in selecting a site is concerned.

In the following Part One this aforementioned set of conditions is briefly summarized for the Göpfritz area.

Part Two, the bulk of our presentation, covers data related to Geology, Geotechnics, Geophysics, and allied fields, gathered and elaborated in the period from 1964 to September 1967.

Part Three briefly describes the geological position of the ring-tunnel, of the beams, and the experimental areas.

To supplement the text presentation by some visual impressions, reference might be made to Part Four containing representative photographs and covering the landscape, exposures, geological and geophysical work, as well as a report on visitors during the period from 1965 to 1967.

The main items of Part Two might be outlined briefly as follows:

Topographically the area is a flat, undulating plateau of about 26·9 km^2, situated at about 580 *m* above sea level; it is covered by pine forest.

Geologically the area belongs to the southern part of the Bohemian Massif; granulites and gneisses are overlain by a thin layer of mainly Quaternary sediments; the bedrock is to be considered as the well-consolidated roof into which Carboniferous granites intruded; since these times it was not influenced by younger tectonics any more.

The stability of the unweathered rocks exceeds considerably the requirements stipulated (modulus of elasticity: granulite 573,000, gneiss 394,000).

Regarding the elements of the site (Part Three), we might mention that

the Göpfritz area is a hill-top site where it will be possible to drain all objects (ring-tunnel, experimental areas, etc.) by gravitation;

the ring-tunnel, assumed to be located at 544 *m*, will be situated in unweathered granulite rock; on about 20% of the circumference of the ring, in the SE section, the rocks are expected to be affected to a moderate extent by joints;

two of the experimental areas (A, 2) are situated in granulite, three (3, B, C) in gneiss, and all of them, of course, in unweathered rock;

the beams (tunnels) connecting experimental areas 3, B and C with the ring will have to penetrate the boundary zone between granulite and gneiss. The results of refraction work show that no major technical difficulties are to be expected here.

For the Austrian authorities it is a pleasant duty, to express their appreciation and gratitude to all those who—sometimes under adverse winter conditions and sometimes under pleasant summer conditions—have cooperated in the various phases of field work at Göpfritz or, who have contributed data by laboratory work in Vienna and Kaprun. Of course, we take pleasure in extending our appreciation to the group of Geneva experts, who, by their visits, not only became friendly associates of the Vienna working group, but by their congenial discussions have greatly contributed toward moulding the site proposal into its present shape.

Résumé

L'efficacité et le succès du fonctionnement d'un quelconque synchrotron à grande énergie sont certes fonctions, en partie du moins, des conditions du sous-sol.

Vu le stade de planification auquel nous nous trouvons actuellement, la stabilité du sous-sol rocheux est considérée comme atout de tout premier ordre pour ce qui est de la construction et du développement technique.

Vu ce fait, la région de Göpfritz a été proposée dès 1965 par l'Autriche en tant que terrain propice à la construction d'un tel centre, son sous-sol de roches dures, sa topographie plate, l'absence de toute activité sismique y constatée constituant une garantie de succès pour une telle entreprise. Il s'agit en outre d'une région inhabitée, de sorte qu'il n'y a pas de complications à attendre de la part de la population locale.

N'oublions pas non plus que les conditions extragéologiques de cette région, à savoir le climat, l'accessibilité, les possibilités de construction, les conditions sociales satisfaisantes — principes élaborés en détails par le C.E.R.N. — constituent autant de facteurs importants pour le choix du lieu d'établissement d'une installation de ce genre.

La première partie de notre exposé traite de ce dernier complexe pour ce qui est de la région de Göpfritz.

La deuxième partie de l'exposé — elle est la plus volumineuse — comporte des précisions géologiques, géotechniques, géophysiques etc. recueillies pendant la période de 1964 à septembre 1967.

La troisième partie du présent exposé donne quelques indications sur l'emplacement géologique du tunnel circulaire, des faisceaux et des installations d'essai.

Nous avons joint dans une quatrième partie du présent exposé, quelques photographies caractéristiques de la région ainsi que des clichés montrant l'exposition, les travaux géologiques et géophysiques réalisés et quelques portraits de personnalités ayant visité le site en question au cours des années 1965/67.

Nous rappelons par la suite les points les plus importants de la deuxième partie de notre exposé :

Topographie :

Il s'agit d'un terrain boisé (forêt de sapins) plat et vallonné de 26·9 kilomètres carrés situé à 580 mètres d'altitude.

Géologie :

Le terrain est situé au sud du massif bohémien. La granulite et le gneiss y sont recouverts d'une couche mince de sédiments d'origine essentiellement quaternaire. La roche de fond constitue un banc bien consolidé avec quelques inclusions de granite carbonifère. Aucun mouvement tectonique ultérieur n'a joué.

La stabilité des roches inaltérées par les intempéries dépasse de loin celle qui a été stipulée (modules d'élasticité de la granulite : 573.000, du gneiss : 394.000).

Pour ce qui est des éléments du site (troisième partie), nous nous bornerons à mentionner que

— le terrain de Göpfritz se trouve situé au haut d'une colline, de sorte qu'il sera possible de drainer tous les bâtiments (tunnel circulaire, terrains d'essais etc.) par la seule gravitation ;

— le tunnel circulaire supposé être construit au niveau de 544 mètres d'altitude se trouvera placé sur de la roche granulitique inaltérée par les intempéries ; dans la partie SE, 20% environ de la circonférence de l'anneau reposeront cependant sur de le roche présentant quelques cassures ;

— deux installations d'essais (A, 2) se trouveront placées sur de la granulite, trois autres (3, B, C) sur du gneiss, toutes les roches étant évidemment inaltérées par les intempéries ;

— les faisceaux (tunnels) reliant les installations d'essais 3, B et C à l'anneau passeront de la zone granulitique à la zone gneissique. Des analyses de réfraction ont cependant démontré que ce passage ne soulèvera sans doute aucune difficulté majeure d'ordre technique.

Les autorités autrichiennes tiennent à remercier tous les savants et chercheurs ayant bien voulu coopérer, dans des conditions très dures en hiver, agréables par contre en été, aux travaux réalisés sur place à Göpfritz, ainsi que ceux qui ont travaillé dans les laboratoires de Vienne et de Kaprun. Elles tiennent surtout à exprimer leur gratitude au groupe d'experts de Genève qui s'est lié d'amitié avec le groupe d'études de Vienne au cours de ses visites et qui a largement contribué à développer les plans actuels de la proposition ayant trait au site de Göpfritz en intervenant dans de nombreuses discussions avec les experts de Vienne.

Zusammenfassung

Die vorgelegten Unterlagen über das Gebiet um Göpfritz sind im Rahmen einer Zusammenarbeit zwischen der Organisation C.E.R.N. und der Geologischen Bundesanstalt, beauftragt durch das Bundesministerium für Unterricht, entstanden. Als Ziel stand vor Augen, solche Grundtatsachen aus dem Bereiche der Geologie, Geophysik und Geotechnik zu erarbeiten, die als Anforderungen für die Aufstellung eines großen Teilchenbeschleunigers (Synchrotron) von der Arbeitsgruppe CERN formuliert worden waren. Diese Bearbeitung weicht von den üblichen Darstellungen insofern ab, als hier die erfaßbaren Grundlagen im Vordergrund stehen, ihre Auswertung für die Geologie des Waldviertels vorläufig bewußt im Hintergrund bleibt; trotzdem ergeben sich aber jetzt schon durch die Intensität der Untersuchungen sowie durch die Vielfalt der angewandten Arbeitsmethoden wichtige Hinweise für neu heranreifende Ergebnisse.

Es sei vermerkt, daß diese deutschsprachige Zusammenfassung nicht eine Wiederholung der in den Abschnitten 2 und 3 gegebenen Daten sein kann, sondern nur ein übersichtlicher Rahmen, in dem Arbeitsgänge und Ergebnisse dargestellt sind. Für alle Fakten wird man nach dem englischsprachigen Text und Beilagen greifen müssen.

Als topographische Grundlage wurde 1966 vom Bundesamt für Eich- und Vermessungswesen eine Karte entworfen, die 1967 für geologische Zwecke erweitert wurde. Das dargestellte Gebiet, „die Wild", ist eine SSW—NNE streichende plateauartige Höhe, die nach N, E und S durch tiefeingeschnittene Täler begrenzt ist. Das ruhige Relief und die Abwesenheit von Siedlungen waren der Ausgangspunkt einer seinerzeit von Prof. Dr. L. Waldmann gegebenen Empfehlung, das Gebiet näher ins Auge zu fassen.

Gleichfalls von Prof. Dr. L. Waldmann stammt die letzte Fassung einer geologischen Übersicht dieses Teiles der südlichen Böhmischen Masse (1958), nach welcher der kristalline Unterbau hier aus Granuliten und Gneisen besteht. Feldaufnahmen und Kernbohrungen haben die Granulitserie mit untergeordneten Serpentineinschlüssen sowie die Gneisserie mit Einschlüssen von Marmor, Graphitschiefern, Quarziten bestätigt.

Die gegenseitige Abgrenzung der durch diese Gesteinsserien eingenommenen Bereiche dürfte auf eine heute konsolidierte, früh- bis vorpalaeozoische Tektonik zurückzuführen sein.

Der Sockel von Kristallingesteinen trägt lokal eine vermutliche tertiäre Verwitterung und ist samt ihr von einer Haut wechselnd mächtigen Quartärs bedeckt (Staublehme bis postquartäre Anmoore).

Hydrogeologische Beobachtungen ergaben, daß im Umkreis des Ortes Göpfritz Grundwässer von verschiedener Zusammensetzung auftreten; diese und die an der Oberfläche nach E abrinnenden Gewässer wurden analysiert. Dort, wo im Bereich der Wild die Oberfläche von quartären Staublehmen oder tertiären Verwitterungskrusten abgedeckt ist, sind die Gesteinsklüfte des Hartgesteinssockels überwiegend trocken, wie sich aus dem Vorhandensein von unverwitterten Pyritkristallen in Kluft-räumen ergibt.

Das geotechnische Gesamtbild beruht im wesentlichen auf folgenden Unterlagen: auf

a) den Ergebnissen einer detaillierten geologischen Oberflächenkartierung;
b) den Ergebnissen von 23 Kernbohrungen, Schächten und Sondiernadeln;
c) den Ergebnissen von verschiedenen Laboruntersuchungen zur Feststellung der technischen Gesteinsparameter.

Durch Anwendung seismischer Methoden wurde einerseits getrachtet, eine geotechnische Information über die Festigkeitsparameter (Geschwindigkeiten) der Gesteinseinheiten als Großkörper zu erhalten sowie das Relief der Oberkante des Hartgesteinskomplexes zu erkunden; anderseits war es das Ziel der Geomagnetik, im Wege der Feststellung von Suszeptibilitätsmaxima die eventuelle Verbreitung von Serpentinlinsen abzugrenzen.

Als Gesamtergebnis ist festzuhalten, daß ein Synchrotronring im Bereich des Hartgesteingebietes der Granulitserie ausgelegt werden kann; die Bereiche der Experimentiergebiete am Ende der Strahlen können nach Abdecken einer Quartär- und Verwitterungskruste im tragenden Fels der Granulit- und Gneisserien ausgelegt werden.

Eine Bilddokumentation soll die technischen Unterlagen abrunden.

Es sei schließlich mit Genugtuung festgehalten, daß sowohl die Zusammenarbeit aller mitarbeitenden österreichischen untersuchenden Stellen und mitarbeitenden Firmen als auch die Verständigung mit den Genfer Fachbearbeitern stets vom erfreulichen Gedanken des Ansteuerns auf ein gemeinsames Ziel auf sachlicher und menschlicher Ebene getragen war.

H. Küpper

Geologische Bundesanstalt

Wien, Oktober 1967

Introduction

In connection with the site selection for the proposed CERN 300 GeV Proton Synchrotron, Austria has submitted in May 1965 a tender, offering the Göpfritz-site, Niederösterreich. Since that time a considerable amount of investigations has been carried out, the results of which are covered by various reports. As at the moment the data available comply with the requirements, the following might be considered as a digest of all the facts.

The maps, sections, well-logs and other data contain many new geological informations; this digest therefore was shaped in such a way (Explanatory Notes etc.), so that the background material prepared, will be accessible also for the Geology of Austria. As a similarly detailed and comprehensive investigation so far was not yet carried out in the Waldviertel, it is hoped that the data collected might serve also as basis for future work.

The following gives a general impression on the various types of work carried out:

Geological field mapping 1964, 1965, 1966, 1967;

Geological supervision of testpits and needle tests, 1967;

Core drilling: 1965 (four drillings, total 106 *m*)
1966 (five drillings, total 228 *m*)
1967 (fourteen drillings, total 564 *m*)

Seismic investigations 1966 7 *km*, 1967 17 *km*

Geomagnetic work 1966, 1967

Laboratory work: chemical, petrological, mineralogical, palynological investigations; rock parameters.

Preparation of topographic (1965) and geological map (1967).

List of enclosures:

Enclosure 1/A: Synoptic map, 1 : 10.000, edition A

Enclosure 1/B: Synoptic map, 1 : 10.000, edition B

Enclosure 2: Geological N-S sections 1 : 10.000

Enclosure 3/a—3/t: 19 well-logs

Enclosure 4/a—4/e: Sections through beam A, 2, 3, B, C.

Further 5 figures and 7 tables in the text and 20 photographs (part four).

Part one: General Information

The principal features of the site proposals are summarized in various reports e. g. CERN 644, Rev. Vol. 1, May 1967, III.

In the following the facts are arranged in the same way as in the report mentioned, but where necessary they were revised up to Sept. 1967.

Geographical location (1) *)

Longitude	15° 25 E
Latitude	48° 45′
Location	18 *km* NW of Horn
	58 *km* N of Krems
	120 *km* NW of Vienna (airport)

Dimensions and topography (2)

Surface area .... 26·9 km^2

Minimum height of ground level above ring-tunnel floor .. 21 *m*
Maximum height.. 52 *m*

Length of beams including experimental areas
beam A .... 2·2 *km*
beam 2 .... 2·5 *km*
beam 3 .... 3·8 *km*
beam B .... 4·0 *km*
beam C .... 4·2 *km*

Nature of the ground (3)

a) Type of ground at level of tunnel: granulite

b) Type of ground at level of Experimental area
A, 2 .... granulit
3, B, C .... gneiss

c) Depth from ground surface
to unweathered rock above tunnel
minimum .... 3 *m*
maximum .... 25 *m*

d) Some mechanical properties (average values of samples)

	Granulit	Serpentine	Gneiss
static modulus of elasticity	668.000	300.000	260.000
dynamic modulus of elasticity	507.000	526.000	665.000
unconfined compression strength ...	1.700	562	1.071

*) Headings refer to CERN report 644, 1967.

Seismic activity of the area (4)

The intensity of the strongest earthquake felt at or near the Göpfritz site is to be classified as IV (degrees Mercalli).

Availability of the area (5) *)

within approximately one year;

Electricity supply (6)

Installations proposed for the supply of

10 MW (at the start): 110 KV line, 15 *km*
100 MW (in 8 years): 220 KV line, 70 *km*
300 MW (in 15 years): 220 KV line, 70 *km*

Cooling water supply (7):

proposed supply of
0·1 m^3/s from Thaya river (distance 12 *km*)
0·5—2 m^3/s from Kamp river (distance 18 *km*)
in both cases max. temp. 16° C.

Accessibility of the site (8)

a) distance to nearest main road:
federal highway No. 4 (Wien—Praha) passes through Göpfritz

b) nearest railway station:
main railroad (Wien—Praha) passes through Göpfritz

c) airports near the site:
distance Göpfritz—Schwechat (Vienna airport) 120 *km*;
driving time to airport 2 *hrs*;
60 regular planes taking off and landing per day;

d) accessibility
Average distance to Göpfritz from the capitals of the Cern Member states in *km*,
with population as weighting factor .... 990 *km*;
with equal weight to all Member states .... 970 *km*;
distance to Geneva .... 750 *km*;

Average number of hours absence from the capitals of the Cern Member states for a one-day meeting at Göpfritz
by plane 42 *h* 50′
by train 66 *h* 40′

Number of hours absence from Geneva for a one-day meeting at Göpfritz
by plane 42 *h*
by train 51 *h* 30′

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*) This and the following items (5 up to 11) are added to round out the information; they are mainly non-geological and non-geotechnical.

e) Population centres near Göpfritz (9)

5,000—50,000 inhabitants within about 40 *km*:

Horn, 5,000, 18 *km*
Gmünd, 7,000, 35 *km*
Krems, 21,000, 58 *km*

over 50,000 inhabitants within about 100 *km*:

St. Pölten, 51,000, 85 *km*
Wien, 1·63 Mill., 105 *km*

Living conditions (10)

two areas proposed, Horn at 18 *km* and Krems at 58 *km* from Göpfritz;

sports and recreation: hunting, fishing, horse-riding, swimming nearby; mountaineering and wintersports at about 200 *km*. Social and cultural activities in Vienna, distance 105 *km*.

f) Meteorological data (extract) (11)

	Göpfritz	(Meyrin)
number of days per year with max. temperature above 30° C	1·4	(8)
number of hours of sunshine per year	1697	(2006)
number of days per year with fog or visibility — 1 *km*	47	(19)
number of days per year with snow coverage ...	86	(22)

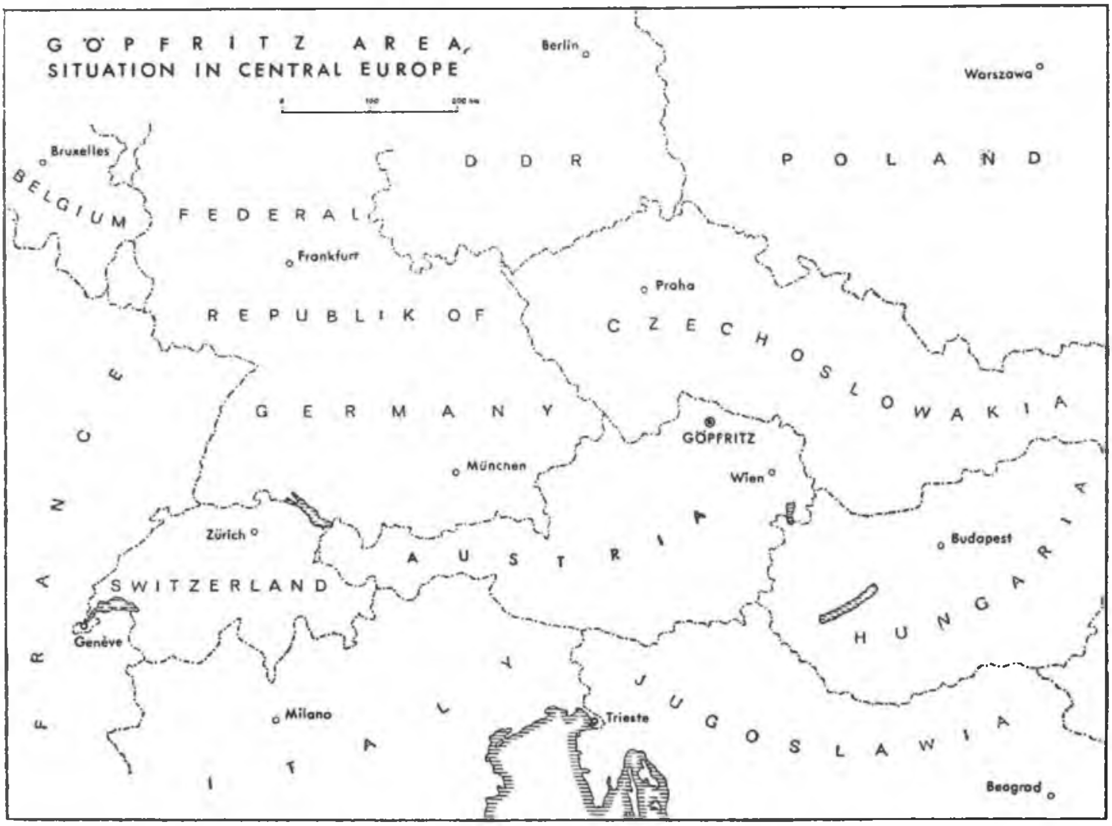


Fig. 1

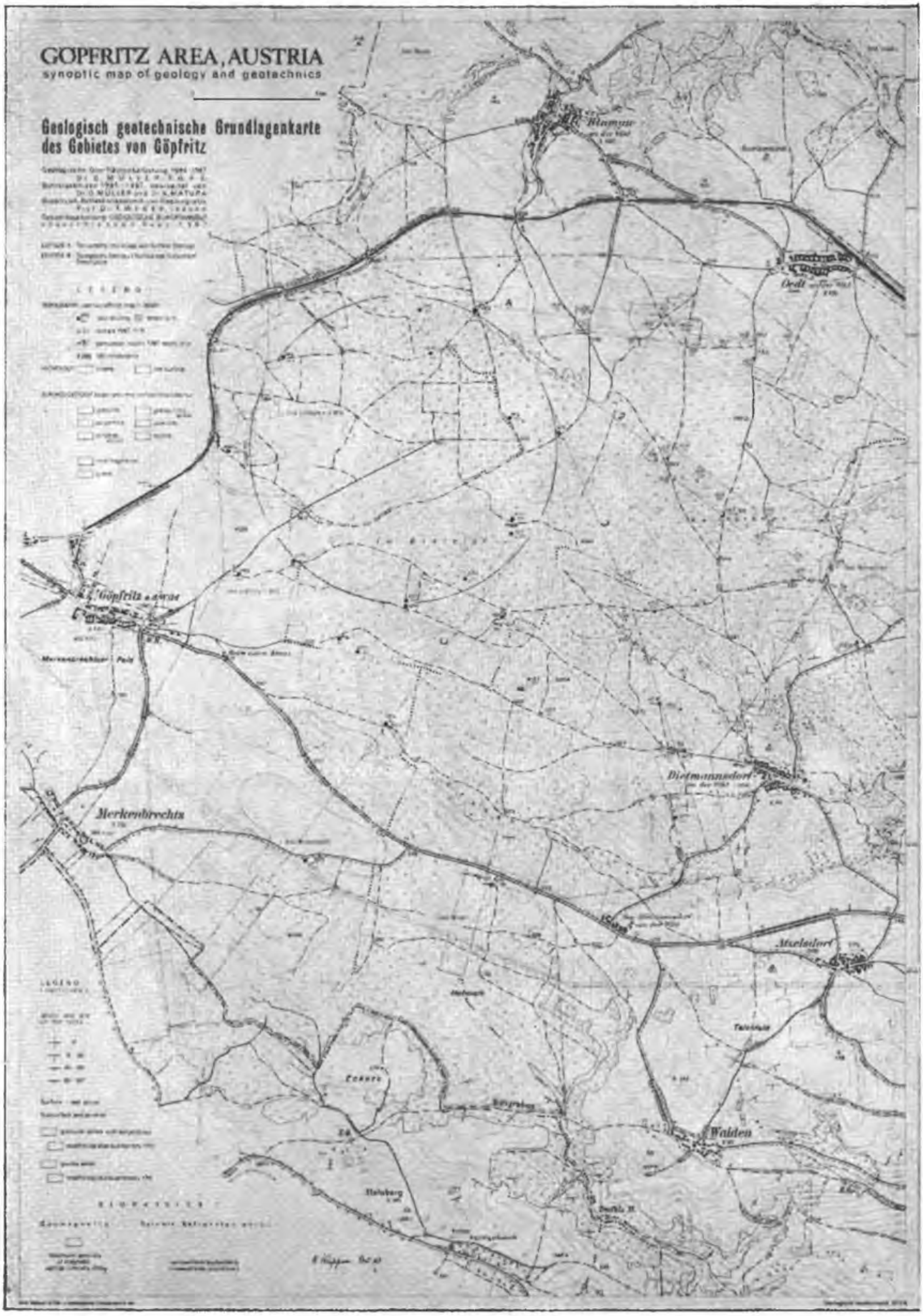

GOPFRITZ AREA, AUSTRIA
synoptic map of geology and geotechnics
Geologisch geotechnische Grundlagenkarte
des Gebietes von Göpfritz
Dietmannsdorf
Merkenbrechts
Walden

Fig. 2

2. Part two: Geology, Geotechnics, Geophysics and Related Fields

2.1. Geology

2.1.1. Topography and General Geology

(see encl. 1/A, 1/B, 2)

The area between the railroad in the N, and the main road (No. 4) and the Höllgraben in the S ist a flat, undulating plateau which drains via small creeks towards N, E and S. The mean elevation inside the area is between

580 *m* and 590 *m*; the maximum is 604 *m*;
the minimum is 560 *m* in the north,
535 *m* in the east and
510 *m* in the south (Höllgraben).

It is mainly covered by pine forest, partly birch vegetation, locally with open, grass-covered wet glades.

The area is shown on a topographical map 1 : 10,000 which was prepared on the basis of all data available. Its accuracy is such, that it might serve as basis for preliminary investigations; elevations are reliable up to one meter; for later work a precision-nivellement will have to be considered.

Geologically the Göpfritz area is situated within the southern part of the Bohemian Massife, consisting of granits, gneisses and various types of metamorphic rocks. These hardrocks are cropping out over large distances, locally however, they are covered by Quaternary solifluction and windblown deposits; the rock surface is partly fresh, but partly deeply weathered, mainly due to Tertiary, or upper Cretaceous weathering.

In our area the granulite-series are a unit of 9·5 *km* north-south, and 12 *km* east-west extension; predominantly they consist of light to dark granulites; along the southern part lenses of serpentine are enclosed.

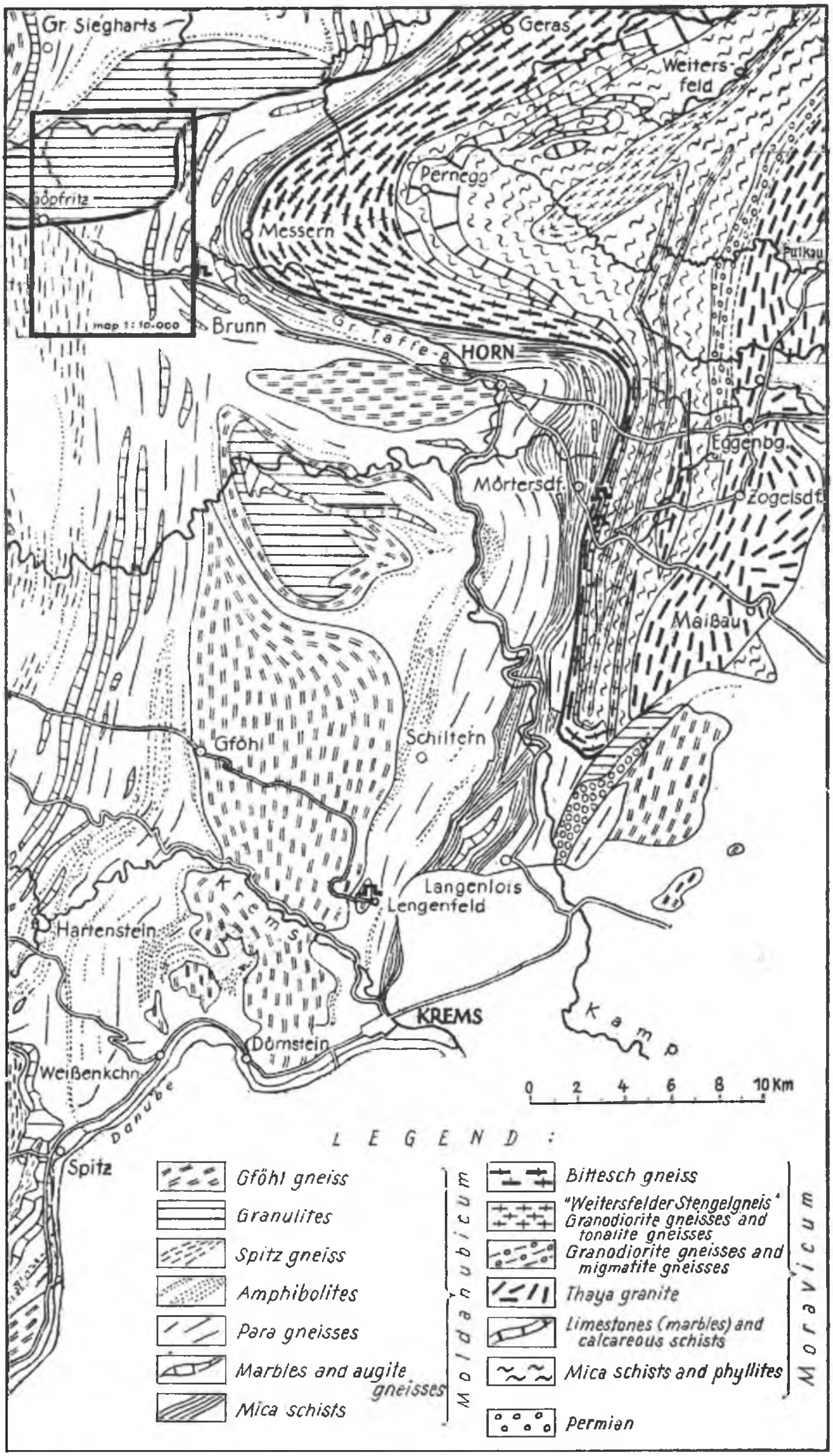
It might be expected that the granulite body extends to considerable depth; at a distance of about 80 *km* NW of Göpfritz in southern Czechoslovakia a deep test for scientific purposes was drilled, which did not yet penetrate the granulite at 570 *m* depth.

The ring is situated in the southern part of the granulite; the experimental areas A, 2 are located in the eastern part of the granulite.

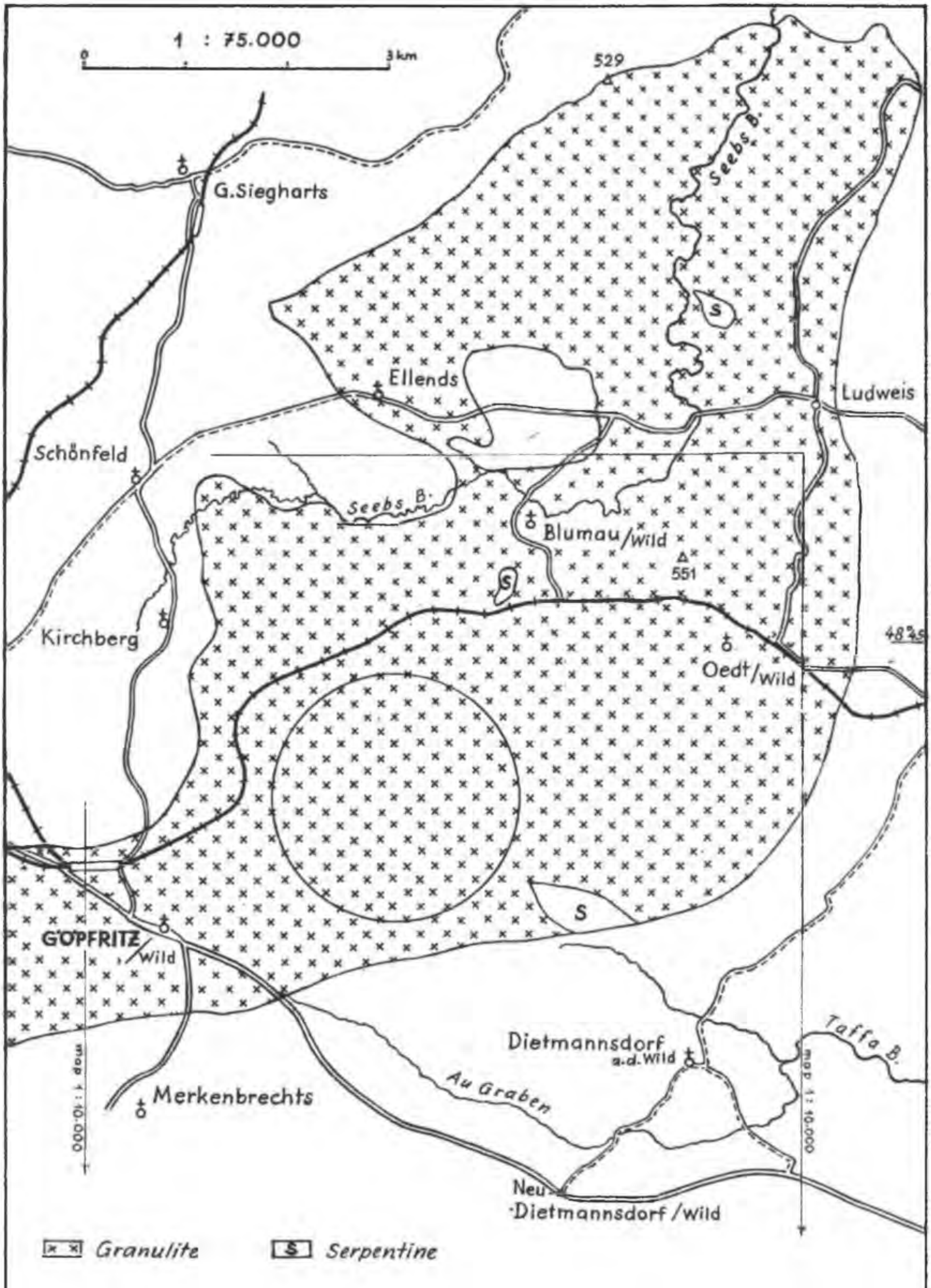
The gneiss-series consist of flat lying, partly eastward dipping paragneisses, with intercalations of marbles, graphite schists, quartzites.

The experimental areas 3, B, C are situated within these gneisses.

The boundary between the above mentioned series consists of a nearly east-west extending zone, where the approximately N—S striking gneisses adjoin abruptly the more massive granulite-body; locally, tectonisation is observed along this boundary-line, e. g. near drilling 66/5.



BOHEMIAN MASSIVE, after L. Waldmann, 1958.
GEOLOGY OF THE REGION BETWEEN GÖPFRITZ AND KREMS
Fig. 3



EXTENSION OF GRANULITE AROUND GÖPFRITZ AREA
according to geological maps published

Fig. 4

2.1.2. Surface deposits and weathering

All sediments, below the surface and above the unweathered hardrock are generalized on the map 1 : 10,000 and on the sections 1 : 10,000 as softrock cover. This cover can be subdivided geologically into a variety of elements; the details of which might have to be considered in connection with local technical questions. For this present outline the following, more general characteristics could serve as orientation; arrangement is from younger to older elements, viz.: dark clays (a), quaternary loam and solifluction (b), amber coloured gravels and boulder fragments (c), weathering in general (d).

Dark clays of sub-recent age (a)

The underground of shallow depressions and the filling of valleys often consists of dark brown to black clays, which sometimes show transitions into peat-like deposits. Prof. Dr. W. Klaus gives the following description of this material:

A number of highly humified soil samples and peat samples from different localities in the vicinity of Göpfritz were collected in the field for pollen analytical investigation. In most cases the plant microfossils are fairly well preserved; they permitted the reconstruction of ancient forest flora. The remarkable uniform assembly of all samples led to the conclusion, that the deposition took place during a younger Postglacial Period, from mediëval up to recent times, during the so called Younger Subatlantikum (Firbas 1949).

Typical features of flora indicate the obvious influence of men. This is documented by the occurrence of cultivated cereals and typical wood selection in the forests. The increase of Pinus is one of the most characteristic features for the Younger Subatlantikum.

Samples containing the aforementioned type of microflora were collected at the following locations:

Location	Lab. No.
Göpfritz, E, Augraben, three samples from Point B, 0—30 *cm* depth	1495, 1496, 1493
Rothweinsdorf	1484
Dietmannsdorf, NW Göpfritz	1515
Fürwald, N	1472

As an example of the microflora of the Göpfritz area pollen analytical results of a sample from village Fürwald, E of Waiden, is shown below:

Arboretic Pollen	74%	Non-Arboretic Pollen	26%
Pinus	81%	Cerealia	9%
Abies	3%	Centaurea cyanus	sporadic
Picea	4%	Plantago	1%
Alnus	7%	Gramineae	3%
Betula	2%	Varia	8%
Quercus	2%	Compositae	7%
Ulmus	1%	Chenopodiaceae	2%
	100%		
Corylus	1%		

Note the predominance of Pinus in the forests and the occurrence of cultivated cereals among the herbs. This floristical combination indicates the time of human afforesting and agriculture.

FIRBAS F. Spät- und nacheiszeitliche Waldgeschichte Mitteleuropas nördlich der Alpen, Bd. 1, Jena 1949.

KLAUS W. Pollendiagramme der Moore des niederösterreichischen Waldviertels (Haslau), Verh. d. Geol. Bundesanstalt, Wien 1960, H. 1.

Quaternary loam (and solifluction material) (b)

In the higher parts of the area the surface is underlain by very compact impermeable grey loam; if weathered, it is light grey, nearly white; about 50 *cm* below the surface it is evenly coloured dull grey; this loam is considered at least partly as windblown deposit (Staublehm).

The fractionation (grainsize) of two samples from testpit 5 had the following results (according to Prof. Dr. J. Fink):

grainsize	2000—60 μ	60—20 μ	20—2 μ	2 μ (clay)
sample 0·2 *m* depth	23%	29%	32%	16%
sample 0·7 *m* depth	19·6%	20%	27%	34%

Below the clays mentioned above, but partly also directly on the surface, brown loam containing angular rock fragments often occurs. These fragments belong to Quaternary solifluction sheets. Partly a gradual transition exists into the underlying brown weathered hardrock; this weathering however is due probably to the Tertiary (tropical) cycle of weathering.

Amber coloured gravels and quarzite fragments (c)

Are observed E of Merkenbrechts and E of Rothweinsdorf, forming a thin cover directly upon the hardrock (e. g. testpit 9); the gravels vary from egg-size to boulders of fist-size and larger; the rock fragments vary within the same range. This screen of gravels and rock fragments is to be considered as relicts of an old (pre-Burdigalien) sedimentary cover of the highest parts of the southern Bohemian Massife. Occasionally larger gravels are wind-faceted, or broken into irregular fragments, which is of course due to exposure under Quaternary climate conditions.

The highest occurrence of these gravels was observed by L. Waldmann from 580 *m* to about 700 *m* outside our area (information 1966); these gravels might be identical with what had been described by R. Hauer 1952 as „Höhenschotter".

Weathering (d)

As mentioned sub b, there exists a transition from Quaternary to Tertiary and possible to older weathering. Additional investigations are required to probe into these problems. It should be mentioned, that the weathering, irrespective of its age, reaches about 5—6 *m* depth; locally however, a kaolinic weathering of the insitu gneisses was found down to about 30 *m* from the surface (drilling 67/r and 67/s).

The pedological and mineralogical situation of the softrock cover is summarized by Dr. H. Kurzweil as follows:

Pedology (according to Prof. Dr. J. Fink):

The observations along shaft-profiles show that the soil cover is developed as (podzolic) brown earth or as pseudogleyic relict soil.

A sequence of $A_{h \text{ or } p}$, (A_e), B, C or D horizons for the first group is common. Soilflow and the rock debris of solifluction are found on the deeply weathered surface of the metamorphic underground.

An A_h, A_e, S, (D) and C profile is typical for the relict soils where soilflow also was found above the basement. The thickness of soil formations varies; normally it is between 50 and 200 *cm*.

Sedimentology and Mineralogy (according to A. Krabichler, H. Kurzweil and G. Woletz)

Grainsize analyses made on samples from drillholes and shafts show that there is a general increase of the clay content downwards from the top of soil horizons; the maximum clay content is about 70 and 130 *cm* below the top. Further down an increase of the coarse grain sizes can be observed.

Furtheron, the nature of the heavy minerals points to the fact, that practically no transportation from far-away rockformations took place. The heavy minerals of the soils are derived from the local underlying metamorphic basement.

The mineral content of the clay fraction was investigated by X-ray. Quartz, feldspars, chlorite, muscovite, vermiculite and kaolinite are the main constituents. Montmorillonite, graphite, garnet and some hornblende are of secondary importance. Due to the distribution of clay along the profile, quartz, feldspars, chlorite and muscovite are enriched near the surface whilst the clay minerals show a tendency to increase downwards.

2.1.3. Hardrock basement; petrography and chemical analysis

(see encl. 1/B, 2, 3/a—3/t)

Rock samples obtained during core drilling, in test pits and exposures were examined petrographically; these data, covering more than hundred thin sections, together with the results of the inspection of the cores are summarized in the graphical well-logs for the drillholes 1966, 1967; they are attached as enclosures 3/a through 3/t.

For an outline of the petrography and for an explanation of the termes applied we refer to the following, prepared by Dr. A. Matura (G. B. A.).

The material examined can be divided into two groups, viz. into the granulite series and the schistose gneiss series.

Granulites are metamorphic rocks, originated under relatively high pt-conditions. Their chemistry varies from acid (granulites sensu stricto), intermediate (plagiogranulites, pyriclase granulites) to basic types (pyriclasites, pyribolites). All these types have been found in the samples examined.

For a more detailed orientation a short description of representative samples follows:

Granulite (B 67/e, 38·4 *m*)

Distinct parallel fabric by preferred orientation of quartz discs, biotite and sillimanite and mineral distribution. Intergranular implication among feldspars and quartz.

Perthitic intergrowth in alkalifeldspar is common. Biotite with strong pleochroism (light yellow to dark red brown) and pleochroic halos.

Composition: 30% quartz, 30% alkalifeldspar, 23% oligoclase, 10% garnet, 5% sillimanite, 1% biotite. Accessories: Rutile, zircon, opaque ore, kyanite.

Pyriclase granulite (B 66/4, 15·3 *m*)

Preferred orientation of quartz discs, biotite flakes and hypersthene. Andesine with antiperthitic intergrowth.

Composition: 40% andesine, 30% quartz, 10% alkalifeldspar, 12% hypersthene, 3% garnet, 2% opaque ore, 2% biotite. Accessories: Apatite, zircon, spinel.

Pyribolite (B 66/2, 33·6 *m*)

Granoblastic tecture. Klinopyroxene is secondary altered. Carbonate dispersely distributed.

Composition: 65% andesine, 15% brown hornblende, 15% klinopyroxene, 5% carbonate. Accessories: Opaque ore, garnet, chlorite, apatite.

As to the applied granulite terminology we may refer to H. G. Scharbert, Tscherm. Min. Petr. Mitt., 3. F., 8, p. 591—598.

The premetamorphic character of the granulites is not yet fully explained. Some chemical data and certain trace elements point to an ortho-origin, whereas some field observations (well developed layering) and other chemical data might support para-origin. Both possiblilities are under discussion.

Partly the granulite series was affected by diaphthoresis and tectonic movements of different intensity. The term „granulite gneiss" is used, if this influence was distinct, but without destroying the granulite features (f. e. chloritic granulite gneiss, aplitic granulite gneiss, pyriclase granulite gneiss). If the effect of diaphthoresis and tectonics, however, left rudiments of granulite features, the term „chloritic gneiss" is used.

Connected with the granulite series serpentine was found, relatively rich in carbonate and with chlorite pseudomorphoses after garnet.

The schistose gneiss series can be derived from sedimentary rocks. The intercalation of quartzite or graphitic rocks or marbles in this series, is an argument supporting this supposition. The schistose gneiss series is represented by arcosic gneisses, usually fine banded, almost free of mica, frequently similar to aplites; schistose gneisses, being the dominant rock type, have a rather high rate of mica.

Detailed descriptions of the thin sections examined are filed at Geological Survey, Vienna.

For an information as to the chemical compositions of the dominant rocks of the Göpfritz area we may refer to the following chemical analyses:

Chemical Analyses by Dr. W. Prodinger

Rock-Type	Granulite		Gneiss	
drilling depth	1965/N 14·9 *m*	test pit 1967 S/11, 5 *m*	1965/S (R1) 27·4 *m*	1967/t 37·4 *m*
SiO_2	68·05	66·05	63·25	57·67
TiO_2	0·70	1·00	0·60	1·00
Al_2O_3	15·97	16·34	16·59	18·61
Fe_2O_3	1·52	2·17	2·97	0·72
FeO	2·73	3·76	3·59	4·91
MnO	0·02	traces	0·05	0·01
CaO	2·44	2·29	4·19	2·02
MgO	1·65	2·32	3·68	4·32
K_2O	1·86	2·28	1·28	3·14
Na_2O	3·78	3·11	3·00	2·05
H_2O. — *)	0·17	0·06	0·24	0·26
H_2O. + **)	0·61	0·53	0·70	1·78
CO_2	0·06	0·04	—	0·26
P_2O_5	0·03	0·11	0·12	0·15
S	0·16	0·30	0·22	1·49
others	—	—	—	1·50 +)
	99·75%	100·36%	100·48%	99·89%
specific gravity	2·77	2·74	2·87	2·75

*) H_2O up to 105° C
**) H_2O above 105° C

+) graphite and organic matter

2.1.4. Tectonics

As already mentioned sub 2.1.1. the boundary between the granulite series and the gneiss series is a nearly east-west trending, straight zone. Along this zone low velocity rocks were found by seismic work around drilling 66/5, which were later confirmed by coring to be tectonized graphitic schists and quartzites. On the other hand seismic investigations did not reveal similar low velocity rocks along beam 3 and B. It is therefore concluded, that along this straight zone elongated bodies of tectonized rocks occur locally only.

Besides the local occurrence of tectonized rocks, this straight boundary line is characterized by the fact, that the flat, eastward dipping gneisses, S of the line, terminate abruptly against the granulite body, the latter showing in its southern part jointing more developed than further N.

There are no definite indications concerning the age of this tectonical zone. No younger rocks were observed along it; furthermore its trend WSW—ENE is certainly different from that of the „Diendorferstörung", about 50 *km* towards SSE, along which latest displacements during the Tertiary are thought possible. Therefore the above mentioned „Göpfritz-Störung" might be considered as an old structural feature of the rock mantle, into which various Carboniferous granites intruded. Of course, during these intrusion our already existing tectonical line might have been reactivated, but indications for a post-Carboniferous reactivation are so far not observed.

By the results of structure drilling and by seismic refraction work reliable data concerning the subsurface-topography of the top of the hardrock-basement were obtained. The total of these features is given on map 1 : 10,000/edition B by violet contourlines, which indicate two E—W trending troughs. We think that these features are not at all related with tectonics, and that they belong to Tertiary, possibly Cretaceous erosional features.

Younger tectonical features which, by still persisting mobility, might influence the stability conditions of the hardrock basement, are not to be expected in the Göpfritz area.

2.2. Water

Most of the precipitation runs off along the surface, as the underground consists mainly of impermeable Quaternary clays or of relatively dense hardrock. The surface is therefore wet or dry according to the rainfall situation. The yearly precipitation at Göpfritz is 650 *mm* (average 1901—1950); the monthly figures for Allentsteig, 7 *km* SW of Göpfritz, average 1901—1960, are the following

J	F	M	A	M	J	J	A	S	O	N	D	
33	33	33	48	69	79	99	77	52	44	38	39	mm

In the underground no continuous groundwater level was observed in the drillings, which is confirmed by the velocity distribution obtained during refraction work. An exception to this rule seems to be the region around and W of drilling 67/b, where at shallow depth (6 *m*) a waterbearing sand was encountered, which might extend towards W, village Göpfritz.

The undulating surface of the area is subdivided by a network of wet zones, which develop downstream into small creeks. The extension of these wet zones has been checked during the geological surface mapping; it is indicated in blue on the map 1 : 10,000/edition A.

The following table 1 gives an impression on the chemical composition of some water samples, collected under various geological conditions:

Table 1

Göpfritz area, chemical composition of water samples

	Surface runoff						Groundwater			
	a	b	c	d	e	f	l	m	n	o
pH	7·1	7·2	7·7	7·5	7·0	7·1	6·7	7·2	6·7	6·65
dGH°	9·4	10·5	14·2	11·1	6·3	6·2	21·5	18·5	7·0	7·4
dKH°	0·8	0·8	1·4	1·4	0·8	0·8	1·4	1·4	0·8	0·8
dNKH°	8·6	9·7	12·8	9·7	5·5	5·4	20·1	17·1	6·2	6·6
CaO *mg/l*	39	62	55	53	43	38	138	124	30	19·5
MgO *mg/l*	40	31	63	42	14	17	55	44	29	20·9
Cl. *mg/l*	20	20	9	7	7	8	32	38	6	6
SO_3 *mg/l*	23	29	23	26	15	37	143	79	9	17
									Na	135·5
									K	0
									Fe	10
									SiO_2	34

Locations

Surface runoff:

a) Seebsbach, Ellends ESE
b) Oeder Taffa, Nonndorf S
c) Kalchgraben Taffa, Rotweinsdorf N
d) Farrenbach, Dietmannsdorf N
e) Farrenbach, Dietmannsdorf WSW
f) Höligraben, Waiden W

groundwater:

l) Göpfritz, railway station
m) Göpfritz E, Berger
n) drilling 67/b, June, 6 *m*
o) drilling 67/b, May, 6 *m*

note: dGH° = German degree total hardness, dKH° = German degree temporary hardness, dNKH° = German degree permanent hardness.

1 German degree (1 dH°) = 0·7 UK degree = 1·045 USA degree = 1·786 French degree
1 German degree means 1 *mg* CaO per 100 *ml* of water
1 French degree means 1 *mg* $CaCO^3$ per 100 *ml* of water
1 UK degree means 1·425 *mg* $CaCO^3$ per 100 *ml* of water
1 USA degree means 1·0209 *mg* $CaCO^3$ per 100 *ml* of water
p_H = hydrogen-ion exponent according to Sörensen

Table 2

Observations on Recharge in Test Pits

	Test Pit S 1			Test Pit S 9			Test Pit S 11		
	Position of Groundwater		esti-mated Recharge	Groundwater		esti-mated Recharge	Groundwater		esti-mated Recharge
	after	*m*		after	*m*		after	*m*	
before pumping.......		1·46			0·8			2·85	
after pumping.......		5·10			1·8			5·75	
			93·2 *l/h*			333 *l/h*			6·5 *l/h*
	7 hours	4·88		4 hours	1·27		5 hours	5·45	
			102·0 *l/h*			78 *l/h*			32·4 *l/h*
	16 hours	4·42		14 hours	1·04		15 hours	5·35	
			63·0 *l/h*			1·6 *l/h*			45·4 *l/h*
	25 hours	4·23		22 hours	0·98		23 hours	5·16	
			4·4 *l/h*			0·1 *l/h*			29·4 *l/h*
	80 hours	3·02		76 hours	0·95		78 hours	4·53	

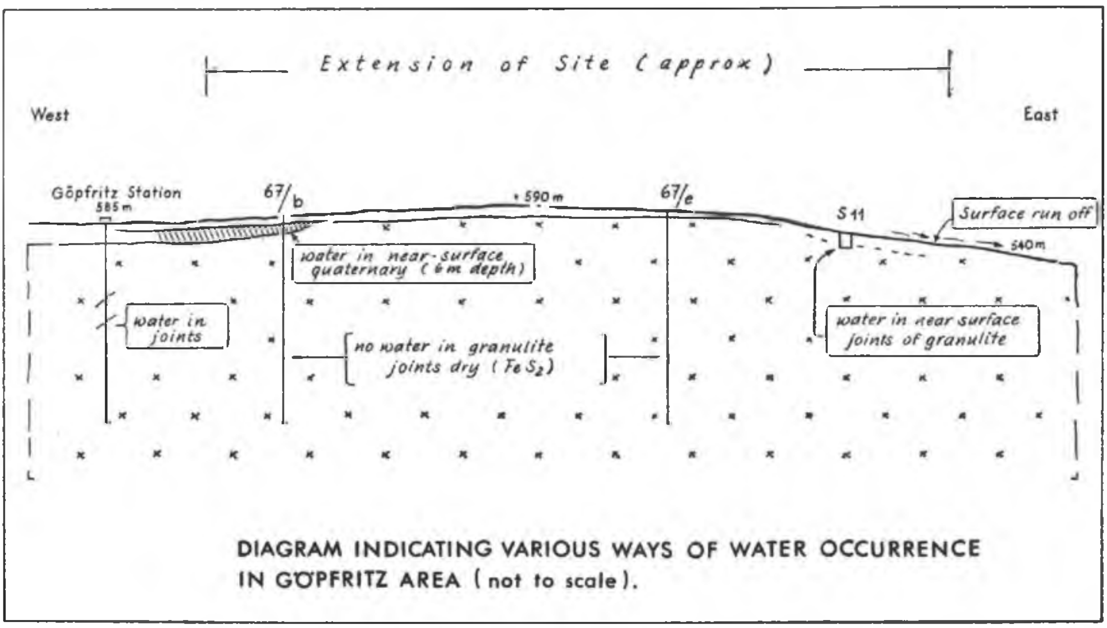

Extension of Site (approx)
West
East
Göpfritz Station
585 m
67/b
590 m
67/e
S 11
Surface run off
540 m
water in near-surface quaternary (6 m depth)
water in joints
no water in granulite joints dry (Fe S2)
water in near surface joints of granulite
DIAGRAM INDICATING VARIOUS WAYS OF WATER OCCURRENCE IN GÖPFRITZ AREA (not to scale).

Fig. 5

2.3. Geotechnics

2.3.1. Core drilling, test pits and needle tests

The 76 *mm* drillholes were intended mainly to check the poorly exposed rock basement. Of course important informations concerning the technical quality of the rocks are provided by observations on the cores obtained and by observations during drilling, such as by core-recovery, number of broken core elements per meter, loss of water during drilling etc.; for an information on these details we might refer to the well-logs of the drillings.

Most test pits, 2 × 2 *m* were carried out for additional information on the type and depth of weathering; their position is indicated on the map and sections.

In order to obtain a general impression on the top hardrock along the beams A, 2 and 3, needle tests were carried out, which penetrated the shallow softrock cover, until they were stopped by hardrock; the information obtained here by is a general one as no samples can be recovered with this method; the location and depth of the needle tests too are given on the map.

The following three tables summarize the above mentioned activities.

Table 3

Summary on Testpit Data, compiled by Dr. G. Müller, S.G.A.E.

Symbol and position	Altitude	final depth	softrock cover	weather-ing	Rock Type	layering (dip)	Ground-water
S 1 on beam A . . .	576	6·0 *m*	0—0·6	0·6—3·1	Granulite	50—80	
S 2 on beam A . . .	567	2·4	0—0·3	0·3—2·4	Granulite	—	none
S 3 A beam 2 . . .	590	2·15	0—0·3	0·3—2·1	Granulite	—	none
S 4 E beam 2 . . .	577	2·2	0—0·4	0·4—2·2	Gneiss	30—50	none
S 5 S beam 2	585	3·0	0—2·9	2·9—3·0	Granulite	—	none
S 6 on beam 3 . . .	583	3·0	0—3·0	—	Kaolinitic Graphite schist	—	none
S 7 on beam 3 . . .	592	3·0	0—0·1	0·1—3·0	Mica schist	40—70	none
S 8 on beam B . . .	582	3·0	0—0·4	0·4—3·0	Gneiss	35	at 2·8 *m*
S 9 on beam C . . .	599	1·8	0—0·5	0·5—1·5	Gneiss	10—20	
S 10 on beam 2 . . .	585	2·0	0—2·0	abandoned		—	—
S 11 on beam 2 . . .	571	6·1	0—0·6	0·6—5·0	Granulite	70—80	

Table 4

Summary of Drilling Results, compiled by Dr. G. Müller, S.G.A.E., Vienna

	Symbol of Drillhole	Altitude a.s.	Final Depth	Softrock cover	Weathered Hardrock	Type of Hardrock	Jointing	Layering (dip) in Hardrock	Occurrence of Ground-water	Loss of Water during Drilling
1965 Sept	E_1 (H_1) *)	599	43	0—30	30—35	Granulite and Serpentine	35—43	10—20°	6—8·5 *m*	high
	N_1 (T_1)	576	22	0— 4	4— 7	Granulite	slight	60—90°	0·5—1 *m*	no
	W_1 (HO_1)	576	25	0— 4	4— 7	Granulite	slight	60—80°	none	low
Nov	S_1 (R_1)	598	30	0—17	17—23	Gneiss	23—30	0—15°	2—3 *m*	high
1966 July	$66/_2$	583	45	0—13	13—19	Granulite and Serpentine	22—23, 32—45	45°	0·5—1 *m*	low
	$66/_1$	588	45	0— 4	4— 7	Granulite	slight	60—90°	none	very high
	$66/_3$	591	56	0—13	13—30	Granulite	30—56	60—80°	0·5—1 *m*	no
	$66/_4$	586	46	0— 3	3— 6	Granulite	slight	60—90°	none	very high
Oct	$66/_5$	595	36	0—30	30—34	Gneiss and Schists	34—36	0—15°	none	very high
1967 March	67/D	573	26	0— 7	7—12	Granulite	slight	60—90°	1—2 *m*	low
	67/C	566	36	0— 3	3—11	Granulite	slight	60—90°	0·5—1 *m*	no
	67/E	584	42	0— 4	4— 8	Granulite	slight	60—90°	0·5—1 *m*	no
	67/A	598	55	0— 4	4—31	Granulite and Serpentine	31—45	56—70°	none	high
	67/F	598	56	0— 7	7—12	Granulite	12—18	60—90°	none	high
	67/K	596	30	0—10	10—20	Granulite and Serpentine	20—30	45—70°	none	high
	67/G	595	55	0— 7	7—30	Granulite	30—55	60—90°	none	very high
	67/B	592	48	0— 6	6—20	Granulite	20—38	45—70°	overflow (0·5 *m*)	no
	67/y	602	40	0—35	35—38	Gneiss	slight	0—15°	none	very high
	67/z	578	15	0— 6	6—11	Gneiss	slight	0—15°	1—2 *m*	no
	67/x	580	30	0—20	20—27	Gneiss	27—30	45°	0·5—1·5 *m*	high
	67/R	571	45	0— 2	2—14	Gneiss	slight	0—15°	none	very high
	67/s	583	40	0—30	30—35	Gneiss and Schists	35—40	0—15°	none	very high
Aug	67/T	580	45	0—31	31—38	Gneiss and Schists	38—45	15—45°	none	very high

*) former symbol

Table 5

Summary on Hard Rock Soundings (needle tests)

Position	Altitude	Depth
Beam A		
n/A/1	553	2·0
n/A/2	563	3·3
n/A/3	570	3·7
n/A/4	575	2·2
n/A/5	576	2·8
n/A/6	577	2·6
n/A/7	575	2·2
n/A/8	577	1·55
n/A/9	575	4·2
n/A/10	574	3·6
n/A/11	574	1·9
n/A/12	575	3·75
Beam 2		
n/2/1	572	5·2
n/2/2	576	4·3
n/2/3	582	2·4
n/2/4	576	2·8
n/2/5	565	1·5
n/2/6	569	2·15
n/2/7	571	2·65
n/2/8	575	2·65
n/2/9	581	2·65
n/2/10	584	3·8
n/2/11	584	3·6
n/2/12	584	2·5
Beam 3		
n/3/1	585	3·4
n/3/2	574	5·6
n/3/3	573	4·9
n/3/4	583	2·95
n/3/5	590	3·65
n/3/6	583	3·8
n/3/7	596	4·0
Beam B		
n/B/7	598	4·3
n/B/8	603	3·2

2.3.2. Data on rock parameters

Rock parameter (a)

Granulites and gneisses belong to those hardrocks, which, when not weathered, can be exposed to very high load pressures. In order to determine approximately the parameters, which apply specifically to the rocks of the Göpfritz area, various laboratory investigations on different rock types were carried out, which are summarized on table 6, prepared by Prof. Dr. E. Clar.

The results of these investigations confirm, that the respective high values for granulites, gneisses and even serpentines are far exceeding the requirements given for the site.

As already indicated the low-velocity rocks near 66/5 are considered as technically not attractive, being evidently tectonized; still it must be mentioned, that even these rocks do have an E-modulus of 226.000, determined by seismic refraction work, which might be indicative for very local tectonization.

Table 6 see page 30.

Pressure tests (b)

In order to obtain an information as to the permeability via fissures, in the granulites along the ring a limited number of pressure tests were carried out, the results of which are given on the following table 7. It has to be emphasized, that out of technical reasons these tests had to be carried out about 1 to 24 *m* above the tunnel axis. As a rough approximation one could say, that in the three wells investigated, at about 30 *m* depth and at a pressure of 10 *at*, the loss of water was between 1 and 8 liters/ per meter/ per minute, which might be considered as a normal low value for slightly jointed rocks at these shallow depths.

Table 7

Pressure Tests

borehole No.	67/a		67/c				67/e		
diam. of hole	76 *mm*		76 *mm*				76 *mm*		
packer	27·9—30·9 *m*		17—20 *m*		30—33 *m*		22·9—25·9 *m*	35·5—38·5 *m*	
pressure at	5	8—9·5	2·5	5	10	15	0·5	5	10
loss of water (*l/m/min*)	3·9 5·3	8·2	12·4	0·7	0·9 1·2	1·3 2·0	11	0·5 1·3	0·6 1·1
	about 24 *m* above tunnel axis		about 1 *m* above tunnel axis				about 8 *m* above tunnel axis		

Summary of Geotechnical Rock-Parameters, compiled by Prof. Dr. E. Clar, University Vienna — Table 6

	Granulite				Serpentine				Gneiss			
	amount of samples	min.	max.	average	amount of samples	min.	max.	average	amount of samples	min.	max.	average
A. Laboratory Investigations on Cores												
A_1 Static E-Modul Determinations by Technical University, Vienna												
Density	13	2·59	2·80	2·70	2	2·48	2·74	2·61	2	2·66	2·71	2·69
Waterabsorption (%) at 1 at	11	0·131	0·855	0·377	1	—	—	0·927	—	—	—	—
Compressive strength, σ_D *kg/cm,*	13	681	3,140	1,698	2	556	566	562	2	725	1,418	1,071
Initial E-Modulus *kg/cm²*	13	431,000	850,000	*668,000*	1	—	—	*300,000*	2	76,000	445,000	*260,000*
maximum value	—	868,000		—	—	352,000		—	—	552,000		—
within σ Intervall *kg/cm²*	—	100—1,096		—	—	326		—	—	50—596		—
Brasilian test σ_Z *kg/cm²*	12	88	333	186	—	—	—	—	—	—	—	—
σ_Z/σ_D	8	0·093	1·139	0·113	—	—	—	—	—	—	—	—
A_2 Dynamic E-Modul Determinations by Laboratory T.K.W., Kaprun												
Density	6	2·72	2·80	2·73	2	2·56	2·81	2·68	2	2·72	2·73	2·72
v/long (p) *m/sec*	6	4,140	5,300	4,655	2	4,155	4,850	4,503	2	4,810	5,120	4,965
v/trans (s) *m/sec*	6	2,250	3,220	2,369	2	2,700	2,920	2,810	2	3,270	3,350	3,310
Poisson coefficient (v)	6	0·21	0·32	0·25	2	0·14	0·21	0·18	2	0·07	0·138	0·104
E-dyn *kg/cm²*	6	348,000	710,000	*507,000*	2	459,000	593,000	*526,000*	2	639,000	692,000	*665,000*
B In situ E-Modul Determinations by Seismic Refraction work, Prof. Dr. F. Weber, Leoben												
Density γ (derived)	—	2·59	2·80	2·70	—	2·56	2·81	2·68	—	2·56	2·72	2·64
Poisson coefficient (derived)	—	—	—	0·25	—	—	—	0·18	—	—	—	0·25
v/long *m/sec*	—	4,500	5,500	5,000	—	4,200	4,800	4,500	—	3,400	5,000	42,00
E-dyn *kg/cm²*	—	445,000	719,000	*573,000*	—	424,000	596,000	*507,000*	—	252,000	582,000	*394,000*

2.4. Geophysics

by Prof. Dr. F. Weber, Leoben

In the years 1966 and 1967 extensive refraction seismic and magnetic measurements were made for the determination of the ring and the experimental areas of the CERN-Project.

The refraction seismic work was started with measurements on the ring (March—April 1966), was continued with reconnaissance work (June 1967) and was finished with a detailed program in the Eastern and Southern part of the area (July—September 1967). The refraction seismic method promised a good applicability because of the strong velocity contrast between the crystalline and the weathered layer.

The total length of the profiles measured on the ring and the 12 seismic lines is 24 *km*; 131 shot holes with depths between 0·5—2·3 *m* were drilled; the charges are between 0·5—1·0 *kg* Gelatine-Donarit per shot. 15 Additional spreads with short geophone distances (2·0 *m*) were shot for the study of the velocities in the weathered layer ("weathering shooting"). Furthermore uphole shootings were performed in the drill holes 67/D and 67/K in 2-meter intervals.

The seismic measurements were performed with a portable 12-channel refraction seismic equipment of the Electro Technical Labs Div./Houston (ER-75-12 Porta-Seis-Interval-Timer), by which the records are recorded on a 4″ × 5″ Polaroid film. Geophones with a natural frequency of 7·5 cps were used. The spread length (distance between the shot points) was generally 180 *m*. The distances of the geophones 1—4 (numbered from the shot point) were 5 *m*, between the other geophones 20 *m*. The shorter distances between the geophones near the shot point were neccessary for the exact determination of the travel time branch of the weathered layer. All the spreads were shot also in the reversed direction. In the areas with considerable thickness of the weathered layer the profiles were measured with a double coverage, i. e. every geophone spread was shot as a normal short spread (distance from the shot point 5—180 *m*) and after this as a long spread (distance from the shot point 180—360 *m*). By this arrangement it is made certain that the unweathered crystalline is always reached.

The selection of a suitable interpretation procedure depends especially on the velocity distribution caused by the geological conditions. Despite of the high quality of the seismic records, interpretation was not a simple and schematic procedure, because of some deviations from the assumptions, generally made in refraction seismic computations (underground is layered, horizons are plane between the shot points, the layers consist of a homogenous isotropic medium and the velocities are therefore constant). Especially troublesome were lateral variations of velocities.

The travel time curves of the Göpfritz area can mostly be considered as 3-layer case. The uppermost layer is only some meters thick and consists of loose materials (humus, loame, sand), which have very low velocities of 250—500 *m/sec*. These values are partly below the air velocity, but they could be measured exactly with weathering shooting. This horizon is not too important for the interpretation because of its small thickness and the fact, that mostly it is checked by drilling. Greater variations in the thickness can result in a scattering of the travel times.

The velocities in the weathered layer below show sometimes rapid variations in horizontal direction, the reasons of which cannot always be determined exactly.

This main weathered layer has often a velocity of 500—1200 *m/sec*. There could be recorded another horizon with a higher velocity (1200—2500 *m/sec*) at a certain number of spreads; this could probably correspond to the strongly weathered crystalline and gravels. This horizon could be found continuously in the North-Eastern and Southern part of the area, it seems to be absent in the central trough extending from the hole 65/E (H 1) to the West.

Below the weathered layer follows always the crystalline underground (hard rock), which is characterizid by high velocity values. Another feature is, that the horizontal velocity variations are by no means irregular, but are in close relation with the petrology of the crystalline. There is a remarkable deviation from this velocity situation in the underground depression where the drill hole 67/y is situated. Here crystalline rocks, consisting of gneisses and schists are so strongly weathered up to depths of more than 30 *m*, that they must have relatively low velocity values of 2500—3500 *m/sec* and just below this the hard rock with velocities of 4000—5500 *m/sec* occurs.

The travel time curve corresponds in these instances with a 4-layer case. On the other side, the corrected travel time curves could be handled as a 2-layer case, where the uppermost layer merges by the correction into the below laying datum plane and where the weathered layer has a homogeneous composition.

For the interpretation a procedure was used, by which the 3- and 4-layer case was reduced step by step to a 2-layer case, the computation of which is rather simple. One has to proceed with the computations from top to bottom, i. e. firstly are the depths and the dip of the first layer computed; the base of this is taken as a new datum plane and then a new travel time curve is drawn, where the travel time is eliminated through the upper layer graphically or by computation. For the computation of the depths and dips of the horizons a method has proven useful, which is a combination of the "critical distance" method and the "intercept time" procedure. Thereby the thin uppermost layer is computed by the critical distance procedure and the deeper boundaries are found by the "intercept time" method.

A comparison between the seismic computed and the drilled depth values of the crystalline shows, that the seismic data are mostly somewhat deeper, than the drilled ones. As this difference is nearly constant, the structure is not influenced by this fact. The structure map of the top hard rock demonstrates, that the underground has a pronounced relief (see encl. 1/B). Especially narrow depressions do influence this relief strongly, which in most cases does not coincide with the surface topography. The greatest thickness of the weathered layer is situated in these troughs, while the thickness on the underground ridges is only some meters.

The velocities of the crystalline presented in an isovelocity map show close relations with the geologic and petrographic conditions. The granulites in the Northern part of the area have throughout high velocities between 4500—5600 *m/sec*. All the closed zones of maximum velocity of more than 5000 *m/sec* are situated in the region of the granulite. Considerable variations of velocities were found in the region of the gneiss-mica schist series (V_L = 3400—5000 *m/sec*).

An extensive minimum zone with velocities lower than 3800 *m/sec* occures in the SE-part of the Göpfritz area; it is probably caused by here abundant mica schists. Especially important is a minimum zone with extremely low velocities of crystalline (as low as 3000 *m/sec*); which was already found at the first run of measurements at the Southermost part of the ring.

The results of two drill holes indicate, that this minimum zone is caused by mylonites and graphitic schists. It can be seen clearly on the isovelocity map, that this zone, unattractive for construction purposes, has a rather small areal extention.

Another part of the seismic program consisted in the determination of the E-modulus (Young's modul) in situ for the different rock types. Measurements in the laboratory indicated, that the density and Poisson's ratios of the different rocks vary within close limits; only therefore the E-modulus is mainly a function of the longitudinal velocity. The following mean values of the E-modulus were determined by seismic means:

Granulite	573,000 kg/cm^2
Serpentine	507,000 kg/cm^2
Gneiss-mica schist	394,000 kg/cm^2
Mylonite-graphitic schist	226,000 kg/cm^2

The ccincidence of the E-moduli determined by seismic work in situ and the values measured in the laboratory on drill cores is quite satisfying.

The question of the eventual existence of water bearing horizons was examined by a detailed study of the velocities in the weathered layer. For areas, where velocities of the main weathered layer attain 500—1200 *m/sec*, the existence of ground water can be excluded with certainty, because the latter has a value of about 1500 *m/sec.* In areas however, where the weathered layer includes horizons with velocity higher than 1500 *m/sec*, drilling results and geoelectric measurements also stem for the conclusion, that there is no continuous groundwater level.

The geoelectric work (Schlumberger electrode arrangement) in the southern part of the Göpfritz area shows a 2—4 layer case, where the boundary towards the underlaying hardrock is clear, because of the infinite resistivity of the latter. The main part of the weathered layer which has relatively high velocity has low resistivities, 40—80 *Ohm/m.* This is considerably below the resistivity range of ground water bearing layers in this area (some 100 *Ohms/m*). A comparison with the drilling results indicates, that these low resistivity values of the weathered layer are caused by a high clay content, which again is the reason for the impermeability of the sediments.

The magnetic measurements (vertical intensity) had primarly the purpose, to determine the extent of the serpentine bodies. The measurements were made in the area of the ring with a distance between the points of measurement of 100 *m*. The theoretical basis for the use of this method is the fact, that serpentine has a considerable higher susceptibility, than granulite and gneiss. It was possible to determine very exactly the serpentine body, outcroping in the Eastern part of the Göpfritz area. Inside of the ring there are only a few small, narrow anomalies. The form of the anomalies demonstrates, that the causing serpentine bodies must be small bodies only, disappearing rapidly in the direction of the elongation of the lenses.

2.5. Synoptic map, Section, Well-logs and Beam-sections

In presenting the data worked out, we thought it useful to prepare these in such a way, so that they eventually could be used immediately for practical purposes.

Therefore, for maps and sections the scale 1 : 10,000 was chosen; with view however to the great amount of data available, we had to prepare two versions of the map, viz.:

Synoptic map 1 : 10,000, version A (encl. 1/A) covers topography including site elements as ring, beams and experimental areas; hydrology, wet surface areas and creeks; surface geology in so far, as each exposure is indicated by a symbol.

Synoptic map 1 : 10,000, version B (encl. 1/B) covers topography; surface geology as for A; subsurface and general geology indicating rock units and Quaternary cover; geophysics and geomagnetics.

Version A therefore might be considered as basis for general planning decisions, version B is more specifically related to the features of the rock-underground and -cover.

Section 1 : 10,000 (encl. 2) is intended mainly as summary information on the ring, however it can be taken also as N—S cross section through the whole site area.

The well-logs (encl. 3/a—3/b) of the core drillings carried out 1966 and 1967 are an extract of all detail observations, eventually a guide, if one later on should want to restudy the core material, stored at the GBA, Vienna. (The cores of the four 1965-wells are no more included here; because of their small dimensions, they did not give results comparable with those of later drillings).

The beam-sections (encl. 4 a—4 e) were prepared by the Geneva office on the basis of those data, which were made available by seismic work and drilling results from June—September 1967.

3. Part three: Elements of the site

3.1. The ring tunnel

(see encl. 2)

The position of the ring tunnel, as planned by the Geneva experts is at 544 *m* a. s. It is situated along its whole circumference in the unweathered granulite.

Approximately between 67/a and 67/g the granulite is jointed, probably due to the position of this section near to the granulite-gneiss boundary; the lenght of this jointed section is abt. 20% of the circumference of the ring.

In the drillings 65/1, 66/2 and 67/a, 67/k intercalations of serpentine, thickness abt. 1—20 *m*, were encountered; according to geophysical investigations the serpentine is expected to occur as local, small-size intercalation within the granulite body. It might be expected in the ring tunnel around drilling 66/2 for a short distance (see section 1 : 10,000).

3.2. Experimental areas and Beam Tunnels

Enclosures 4/a up to 4/c cover all data concerning Experimental areas and Beam tunnels, they were prepared at Geneva in close cooperation with the Vienna group on the basis of the seismic investigations and geological work, conducted during summer 1967. The following is a brief information on the respective Experimental areas.

Experimental area on Beam A (encl. 4/a):

It is situated in open, slightly undulating country, covered by forest, meadows and fields,

test pit 1, elevation 576 *m*, reached dark, splintery, unweathered granulite at 572 *m*,

slight water seepage was observed during digging of test pit 1, two months after completion of the pit recharge was determined by a pumping test as 75 *l/h*,

the base level for excavation is assumed here at 566 *m*, which would involve abt. 1·7 Mill. m^3 excavation.

Experimental area on Beam 2 (encl. 4/b):

It is situated in forest country on an eastward slope,

test pit 11, elevation 571 *m*, reached splintery, unweathered granulite at 568 *m*,

slight water seepage was observed during digging of test pit 11; two months after completion of the pit recharge was determined by a pumping test at 32 *l/h*,

the base level for excavation is assumed as 567 *m*, which would involve abt. 2·4 Mill. m^3 excavation.

Experimental area on Beam 3 (encl. 4/c):

It is situated in open country, covered by fields, accentuated topography, slope towards S,

drillings 67/r, 67/s, 67/t attained the top of the unweathered gneisses at respectively 548·5 *m*, 554 *m* and 568·5 *m*,

no water seepages are observed in test pit or drillings,

the base level for excavation is assumed at 553 *m*, which would mean abt. 3 Mill. m^3 rock displacement.

Experimental area on Beam B (encl. 4/d):

It is situated in slightly undulating forest country,

on the basis of the topographical position of exposures of unweathered gneiss in the Augraben, further, of the top of the unweathered gneisses in drilling 67/z at 8 *m* depth and finally of the same rocks in test pit 8 at 2·8 *m* depth, it is suggested to place the base level for excavation here at 565 *m*,

this would mean excavating of 2·5 Mill. m^3.

Experimental area on Beam C (encl. 4/e):

It is situated in practically flat, forest country, with a wet surface in the southern part,

water seepage was observed in test pit S 9, by a pumping test recharge was determined as 13 *l/h*, two months after digging S 9,

on the basis of refraction work the top hardrock could be determined at abt. 10 *m* below the surface,

therefore the base level for excavation is assumed here at 580 *m*, which would mean abt. 3·2 Mill. m^3 of excavation.

The geological position of the Beam-tunnels, connecting the Ring-tunnel with the Experimental areas, is indicated on enclosures 4/a—4/e.

As an additional information it might be mentioned here, that the presence of relatively shallow hardrock was confirmed by seismic refraction work abt. 1 *km* SSE of Göpfritz village. As in this region originally Beam 6 was planned, which is no more under consideration at the moment, it might be stated as a note for eventual future reference, that here indeed another experimental area could be considered.

4. Part four: Illustrations

The following photographs are intended to present a visual impression on the Göpfritz area and on the activities carried out; they cover landscape (1—3) geology and exposures (4—9), geotechnics (10, 11), geophysics (12, 13), rock-cores from drillings (14, 15) and visitors to the area (16—20).

1. Main road Vienna—Praha crosses southern part of area
2. Forest area near drilling 1967/x
3. Near center of ring
4. The only good granulite exposure of the area E Schönfeld, N of Göpfritz
5. Serpentine exposure NW of Dietmannsdorf
6. Test pit S 11 reached unweathered granulite
7. Gneiss under weathered cover, in test pit S 8
8. Impermeable Quaternary loam, light grey on top, dark grey below, covers weathered solifluction in test pit S 5
9. Gneiss with intercalations of graphite schist is locally weathered in situ into white kaolinic softrock, test pit S 6
10. Core drilling 1967/z, summer 1967
11. Top hardrock checked by "needle" tests, summer 1967
12. Portable recording outfit for refraction work, autumn 1967
13. Shooting for refraction work in soft surface clay near drilling 1967/x, autumn 1967

14 a) above: granulite cores, drilling 1967/b, 37—42 *m*
   b) below: gneiss cores, drilling 1967/z, 8—11 *m*

15. Cores of serpentine rock, drilling 1967/a, 17—19 *m*
16. Winter visit of CERN experts, N part of Göpfritz area, winter 1966
17. Mr. Bjerrum visits area summer 1967
18. Prof. J. J. Graham, Stanford Univ., looks at seismic records autumn 1967
19. Dr. Th. Piffl-Perčević, Austrian Minister of Education, listening to geotechnical explanations, summer 1967
20. Geneva experts discussing results in Göpfritz village, summer 1967

1. Main road Vienna—Praha crosses southern part of area

2. Forest area near drilling 1967/x

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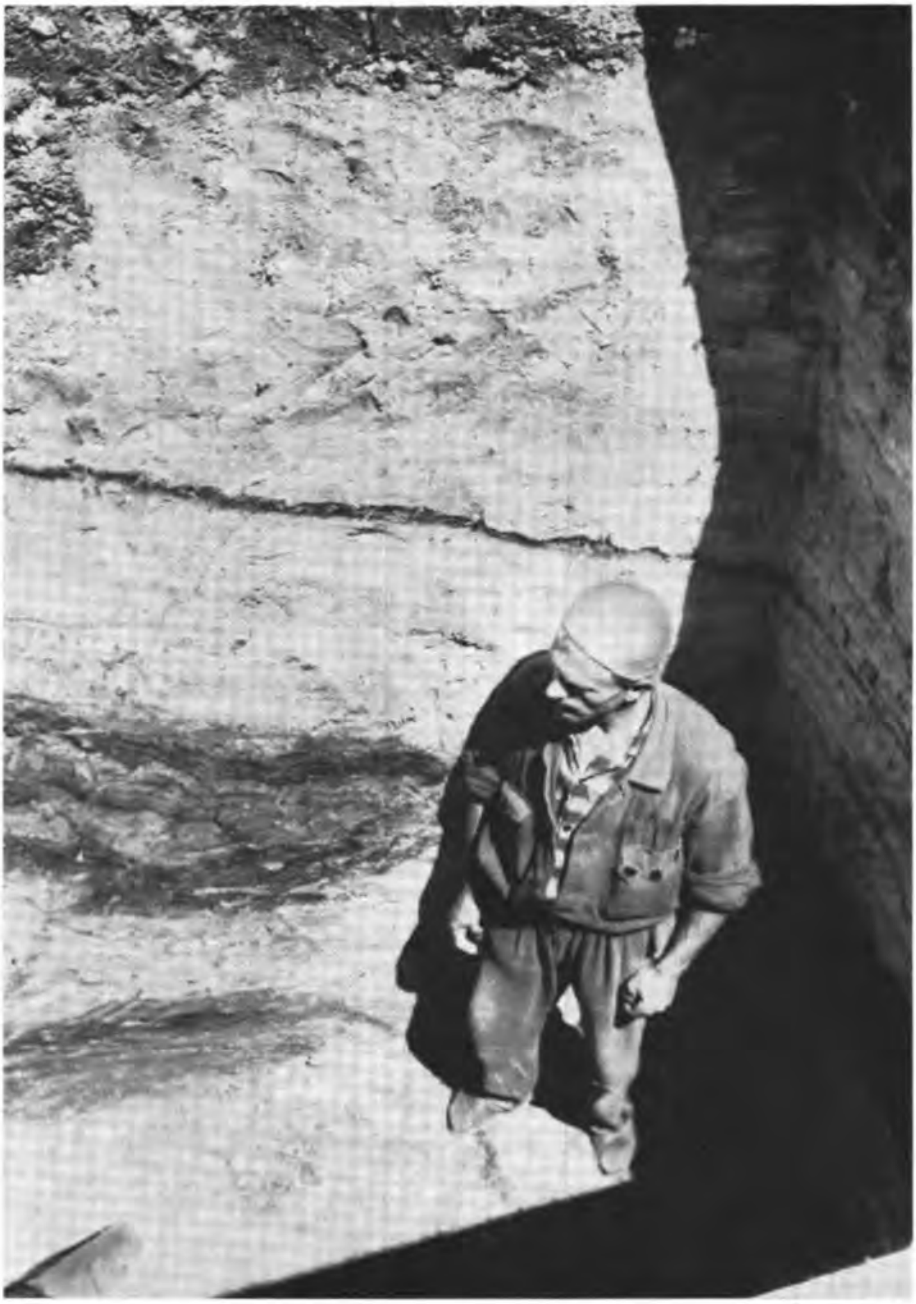
4. The only good granulite exposure of the area, E Schönfeld, N of Göpfritz

5. Serpentine exposure NW of Dietmannsdorf

6. Test pit S 11 reached unweathered granulite

7. Gneiss under weathered cover in test pit S 8

8. Impermeable quaternary loam, light grey on top, dark grey below, covers weathered solifluction in test pit S 5



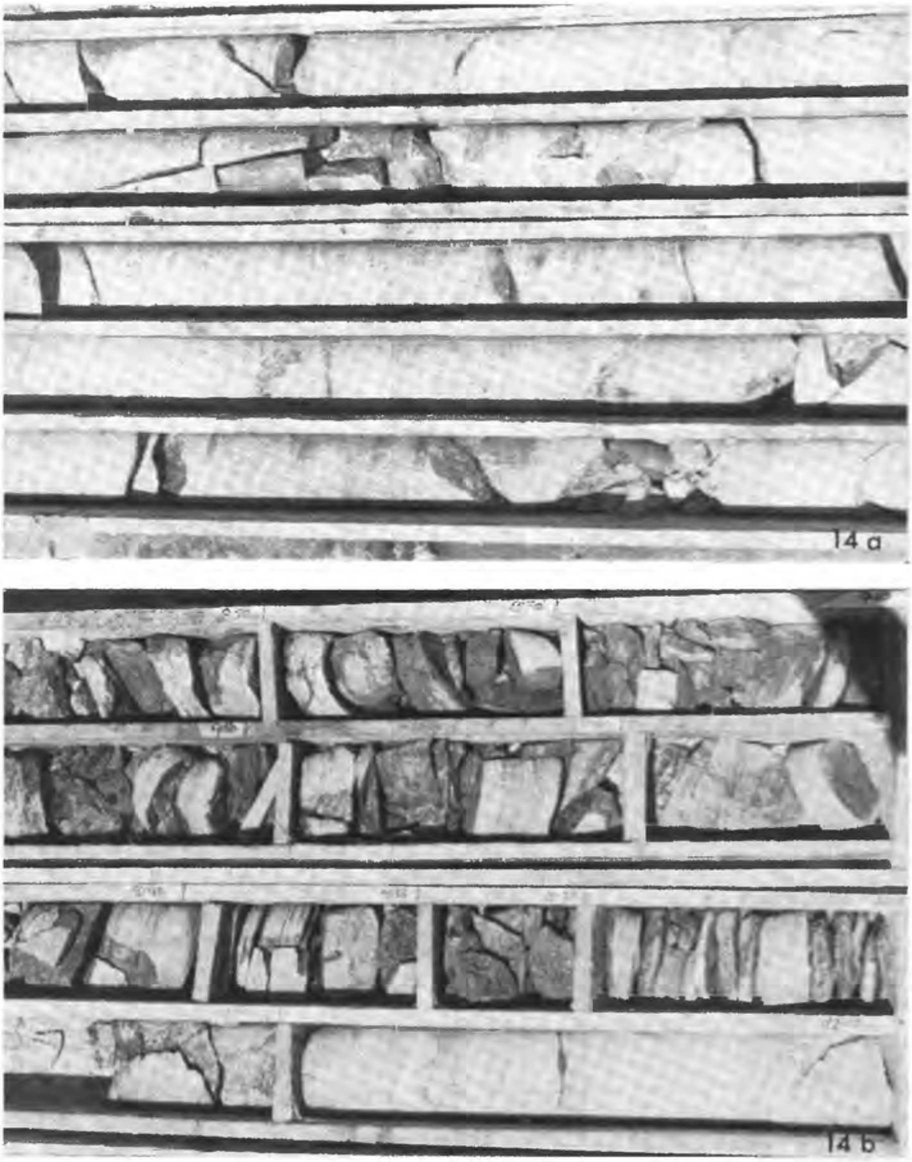
9. Gneiss with intercalations of graphite schist is locally weathered in situ into white kaolinic softrock, test pit S 6

110. Core drilling 1967/z, summer 1967

11. Top hardrock checked by "needle" tests, summer 1967

12. Portable recording outfit for refraction work, autumn 1967

13. **Shooting for refraction work in soft surface clay near drilling 1967/x, autumn 1967**



14 a) above: granulite cores, drilling 1967/b, 37—42 *m*
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