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CONSULTING GEOTECHNICAL ENGINEERS

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REPORT NO. 6
HAT CREEK GEOTECHNICAL STUDY
VOLUME 3 - APPENDICES 2-6

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PETROGRAPHIC REPORTS

APPENDIX 2

PETROGRAPHIC REPORTS

In order to substantiate the findings of the geotechnical test results and visual descriptions, thin sections were cut of a number of representative rock types. The sections were cut and described by Vancouver Petrographics Ltd.

A number of petrographic descriptions were also provided by Dolmage-Campbell & Associates in a draft report. These are not reproduced in this appendix; they confirm the descriptions made on the GA geological logs.

Vancouver Petrographics Ltd.

JAMES VINNELL, Manager
JOHN G. PAYNE, Ph. D. Geologist

216 EAST 28TH AVENUE
VANCOUVER, B.C. V5V 3M1

PHONE (604) 874-1650

PETROGRAPHIC EXAMINATION
FOR
GOLDER BRAWNER & ASSOCIATES LTD.

#803 - 206.2 and #803 - 353 examined over transmitted light.

September 1976

Pilsum P. Master M.Sc.

803 - 206.2 : TUFF

The rock is fragmental. The fragments can be distinguished from the matrix by: (1) the groundmass is hydrated to palagonite (yellow colour), (2) the larger size of the glass beads. In general, the fragments are etched and are subangular.

There is a great abundance of pore spaces, which have an irregular shape and distribution.

Upto 5% (visual estimate) of the rock is made up of subhedral medium sized grains of feldspar (K-spar and plagioclase). These crystal grains have an irregular distribution, and occur as individual grains rather than in clots or mosaics.

The glass is variable in form, size and amount of devitrification. The glass beads are generally round in shape(in X section), or oblong. Some of the beads have iron rich (limonite?) rims. Part of the groundmass is a microcrystalline aggregate in the shape of shards (montmorillonite).

Before devitrification and chemical alteration to montmorillonite, the rock was most probably a TUFF ---an admixture of glass fragments, rock fragments and whole crystals. The "rock" fragments were most probably older tuff of similar composition. Due to the relatively large size and subangular shape of the fragments the rock may be classified as an agglomerate.

---

803 - 353 : TUFF

This is a relatively uniform rock. The groundmass is a microcrystalline aggregate of shards (montmorillonite). Scattered in the groundmass are fairly uniform sized glass beads. The distribution of these beads is fairly uniform and show no flow texture or lineation.

There are also a few medium sized grains of feldspar scattered through the thin section. In comparison with 803-206.2, there appears to be little or no pore space and no palagonite.

Before devitrification and chemical alteration to montmorillonite the rock was an admixture of vitric and lithic tuff.

Vancouver Petrographics Ltd.

JAMES VINNELL, Manager
JOHN G. PAYNE, Ph. D. Geologist

P.O. BOX 39
8887 NASH STREET
FORT LANGLEY, B.C.
VOX 1JO

PHONE (604) 533-1155

Report for: Graham Rawlings,
Golder-Brawner

Samples: 809-433, 814-596, 898-227.4 (no section)

Sample 809-433 Bentonite with Volcanic Fragments

The rock consists of fragments of mineral grains and fine grained porphyritic volcanic rocks (andesite, basalt(?)) in a groundmass of montmorillonite.

Mineral fragments include quartz, plagioclase, and muscovite; they occupy about 10-15% of the rock, with quartz most abundant and muscovite rare. Fragments range from very fine (0.02mm) up to 0.3 mm, with most obvious fragments being from 0.1 to 0.2 mm in size. The quartz fragments are very angular and plagioclase less angular. Other resistant mineral grains include zircon (one grain 0.025 mm long) and sphene (0.1%) as fractured grains.

Rock fragments include the following types, their compositions are probably andesite, but a few may be basalt. (10-15% of rock)

1) Patches of strongly altered(?) plagioclase grains to 0.05 mm and a few strongly zoned plagioclase phenocrysts of similar size occur in a groundmass of abundant plagioclase laths to 0.025 mm and a very fine grained matrix (0.001-0.005 mm) of unidentified minerals.
2) Uniform rock composed of plagioclase laths to 0.02 mm long.
3) Lathy plagioclase to 0.025 mm with abundant Ti-oxide and opaque up to 0.5 mm across.
4) Lathy plagioclase to 0.1 mm, some showing prominent flow foliation, with abundant interstitial opaque (5-30% in different fragments) and a brown platy mineral (possibly montmorillonite).
5) Sedimentary rock(?) with a few fragments of quartz and plagioclase to 0.1 mm in a very fine grained, strongly interlocking matrix (0.005 mm) of quartz, plagioclase, and clay(?).
6) Sedimentary rock or altered rock: very fine grained interlocking clay minerals up to 0.1 mm across.

As well the rock contains patches of montmorillonite consisting of fibrous aggregates of grains. Patches are up to 0.2 mm across, with grains up to 0.02 mm long. Identifying properties are low relief (R.I. less than quartz), colorless to brown, biaxial -'ve, 2V about 30^{o}, length slow, subparallel to parallel extinction.

A few fragments consist of cryptocrystalline(?) grains with a deep olive green-brown color.

The groundmass (75% of the rock) consists of very fine fragments of minerals in montmorillonite.

The rock fragments range from rounded to semi angular, and are much more rounded than the quartz and plagioclase, perhaps reflecting a high content of montmorillonite in their matrices.

Sample 814-596   Reworked Volcanic Tuff - Bentonite

The rock is layered, the small layer at the corner of the section is described first.

This layer consists of subangular to subrounded fragments of quartz(10%), plagioclase(10%), cryptocrystalline quartz(?)(3%), and muscovite (1%) from 0.01 to 0.1 mm across in a matrix (0.001-0.01 mm) of montmorillonite with limonite staining. The rock contains lenses (15%) from very fine up to 0.4 mm across of coal (opaque). These are parallel to layering.

The main layer contains 30% fragments of quartz and plagioclase up to 0.1 mm (locally 0.15 mm) across. Plagioclase is slightly altered to sericite and dusty opaque, and is more abundant than quartz. Quartz is angular in outline. A few grains of apatite are 0.025 mm long.

The rock contains patches (10%) up to 0.2 mm of fine grained aggregates of montmorillonite. Coarser fragments tend to contain fibrous aggregates and parallel growths ranging in color from white to light brown. In some extinction is irregular. Optical properties are similar to those of montmorillonite described in section 809-433. Some patches contain abundant inclusions of Ti-oxide (0.002-0.005 mm).

As well the rock contains several large fragments up to 10 mm long consisting of brown montmorillonite-chlorite(?) with 5% opaque as fine grained spots and lenses. These fragments are also flattened parallel to compositional layers.

One fragment is dark brown in color, very fine grained, and apparently isotropic; it is rimmed by fine grained brown montmorillonite or chlorite.

The groundmass consists of irregularly grained (0.001-0.005 mm) montmorillonite with minor limonite stain; grains are interlocking to granular. A similar texture occurs in some coarser grained patches of montmorillonite; these may represent altered fragments or just more coarsely recrystallized and altered groundmass.

One patch 5 mm across consists of opaque (coal).

The degree of rounding of fragments, especially in the layer at one end of the section, and the lack of fragments of volcanic rocks suggests that this sample is further from the source and has been more reworked than sample 809-433. The abundance of angular fragments, particularly of quartz, suggests that the degree of reworking is still not great.

It may be significant that the thin layer at one end of the section contains the most-rounded mineral grains and also contains the major coal seam; suggesting that it is more reworked than the other part of the section.

John Payne

John Payne,
November, 1976.

Thin section: Golder Brawner D.D. 44 - 2200'

Mineralogy and mode:

major (>5%)		minor (<5%)		trace (<1%)
plagioclase	26	biotite	4	zircon
sanidine	12	glass	4	apatite
white mica	14	quartz	4	amphibole
carbonate	8	zeolites	4	opaques

Fabric and texture:

Fragmental fabric consisting of sub-angular to sub-rounded lithic fragments and mineral grains in a fine-grained matrix. Tentatively, the matrix is composed of varying proportions of white mica, carbonate, clays, and zeolites. Positive identification of the constituents in the matrix is precluded by the extremely fine grain size.

Suspended in the matrix are lithic fragments of variable composition and shards of mineral grains. The mineral grains are sub-angular to sub-rounded fragments of former euhedral to subhedral plagioclase (An), sanidine, and quartz. Combined carlsbad-albite twinning of the plagioclase is common, whereas only carlsbad twinning predominates in the sanidine. The feldspar grains are often shattered in situ. Quartz grains are generally sub-rounded, but embayment of the grain boundaries is not evident. Faint undulatory extinction is occassionally visible. Deformed biotite flakes are locally part of the matrix, as well as rounded grains of zircon and opaque minerals.

Lithic fragments range from andesitic to dacitic in composition, with approximately a 5:1 andesite:dacite ratio. The fragments are in general holocrystalline, panidiomorphic-granular, porphyritic rocks with a pilotaxitic groundmass. Euhedral to subhedral phenocrysts of plagioclase, and less commonly biotite and/or quartz, are in a groundmass of crowded plagioclase microlites disposed in a sub-parallel manner. The fragments are most often sub-rounded in shape. Occurring less frequently are lithic fragments of hypocrystalline, panidiomorphic-granular, porphyritic texture. The groundmass consists of dark brown glass, occasionally microspherulitic, in which euhedral zoned plagioclase, biotite, and sanidine phenocrysts are set.

Alteration:

There is no evidence for hypogene hydrothermal alteration. Supergene (or diagenetic) processes account for the alteration assemblages which occur. The degree of alteration is variable within the fragments; some are fresh whereas others are pervasively replaced by white mica and carbonate. The phenocrysts in both the groundmass and the lithic fragments are fresh, although a few are incipiently altered to carbonate.

Classification and discussion:

The rock is a tuffaceous conglomerate in the sense that it resembles and in large part derived from pyroclastic debris or extrusive volcanic flows. Several attributes suggest that it is of sub-aqueous and perhaps fluvial origin. There is an absence of grading which would be expected in a sub-areal ash-fall. Moreover, there is no evidence of welding or flow banding in the matrix suggestive of the higher temperatures attendant pyroclastic origin. The lightic fragments are partially rounded; however, the phenocryst shards in the groundmass are more often sub-angular. This is suggestive of minimal transport from the source to the depositional site. The lithic fragments are most certainly derived from the underlying Cedar volcanics.

Mark S. Bloom

Thin Section:Golder Brawner D.D. 816 - 777.5'

Mineralogy and mode:

andesine-oligoclase groundmass	90
zeolites	8
opaques	2

Fabric and texture:

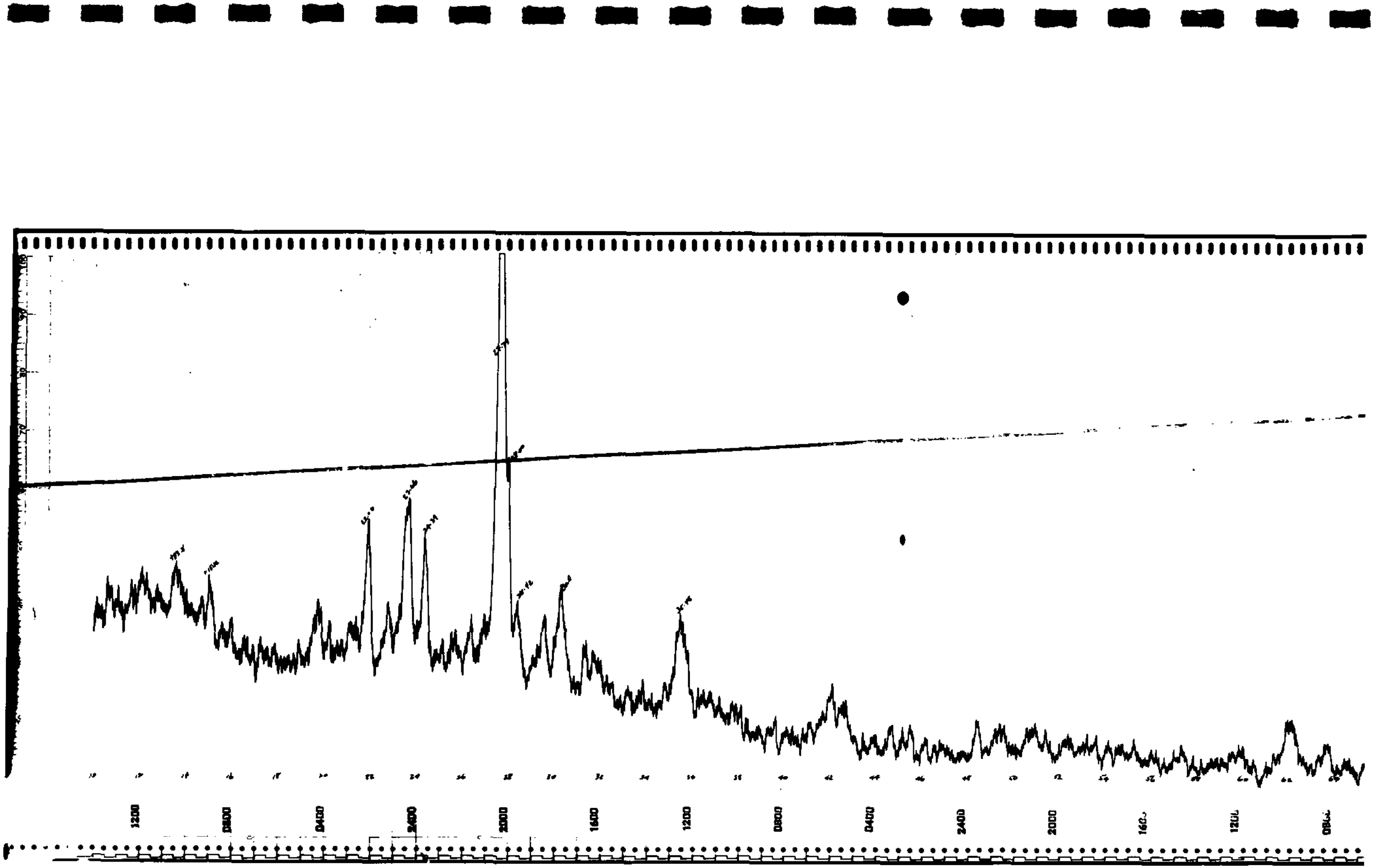
Pilotaxitic groundmass, i.e., crowded euhedral to subhedral plagioclase microlites disposed in a sub-parallel manner. Elongated areas shaded by increased opaque mineral content are possibly relic lithic fragments.

Elongated amygdaloidal cavaties prescribe to a regular concentric sequence of mineralization. From the groundmass into the amygdule, this sequence is a brown, colloidal material (possibly chlorite) which is in turn covered by a colloform, fibrous zeolite. The final phase of mineralization is crystallization of euhedral to subhedral zeolites in the core.

Classification and discussion:

On the basis of the information at hand, I suggest that this rock is an amygdaloidal andesite. The exceedingly fine grain size renders microscopic identification of groundmass const-tuents at best tentative; however, an X-ray powder pattern confirms the presence of andesine-oligoclase. There is no evidence for hypogene hydrothermal alteration, and the filled amygdules are unaltered as well. There is no evidence for strong shearing of the rock; plagioclase microlites are regularly oriented, euhedral, and optically continuous.

Mark S. Bloom



X-RAY DIFFRACTION PATTERN OF ROCK SAMPLE FROM DDH 76-816 AT 777.5'.

APPENDIX 3

X-RAY DIFFRACTION STUDIES

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X-RAY DIFFRACTION STUDIES

Analysis of the mineralogy of the rocks of the Coldwater Formation sequence by X-ray diffraction has been undertaken by the University of Western Ontario for GA and by the University of British Columbia directly for BCH. The University of Western Ontario reports are included in this appendix in their entirety. A summary of the UBC results is also included.

Four analyses of clay samples arising from the coal sampling for Birtley Engineering are also contained in this appendix.

The previous X-ray diffraction work carried out by the University of Western Ontario for Dolmage-Campbell & Associates is not included here, but may be found in the DCA Rock Mechanics Report dated 1975.

JUL 2...

The University of Western Ontario, London, Canada

Faculty of Engineering Science

26 July 1976

Mr. G. Rawlings
Golder, Brawner & Associates Ltd.
224 West 8th Avenue
Vancouver, British Columbia
V5Y 1N5

Dear Mr. Rawlings:

Hat Creek Project - Mineralogical Analyses

I am pleased to enclose two copies of our first set of x-ray and carbonate data for nine separate specimens received between June 24 and July 15, 1976. As I mentioned by phone, we are set up with a scheme that will enable us to mail you back the x-ray and carbonate data within one week of receipt of the samples.

Since we seem to be receiving samples from two or three people, and since the samples are not arriving in any particular order, I have presented the data in the sequence received as noted on the table.

Basically, the soils received so far all contain abundant montmorillonite plus quartz and feldspar as noted on the x-ray powder patterns. Two samples contain abundant carbonate (DH 803, 595' - 596' and DDH 803, 316' - 318'). For the present time, we have tentatively identified the carbonate as an impure siderite since peaks for calcite and dolomite are absent on the x-ray traces.

I hope that this format meets with your approval, and look forward to your comments. Selected glycol retentions and Na^+ analyses will be run when we have a more complete suite of samples or at your instruction.

Yours sincerely,

R.M. Quigley

R.M. Quigley
Professor and Head
Geotechnical Section

RMQ:em
Enclosures

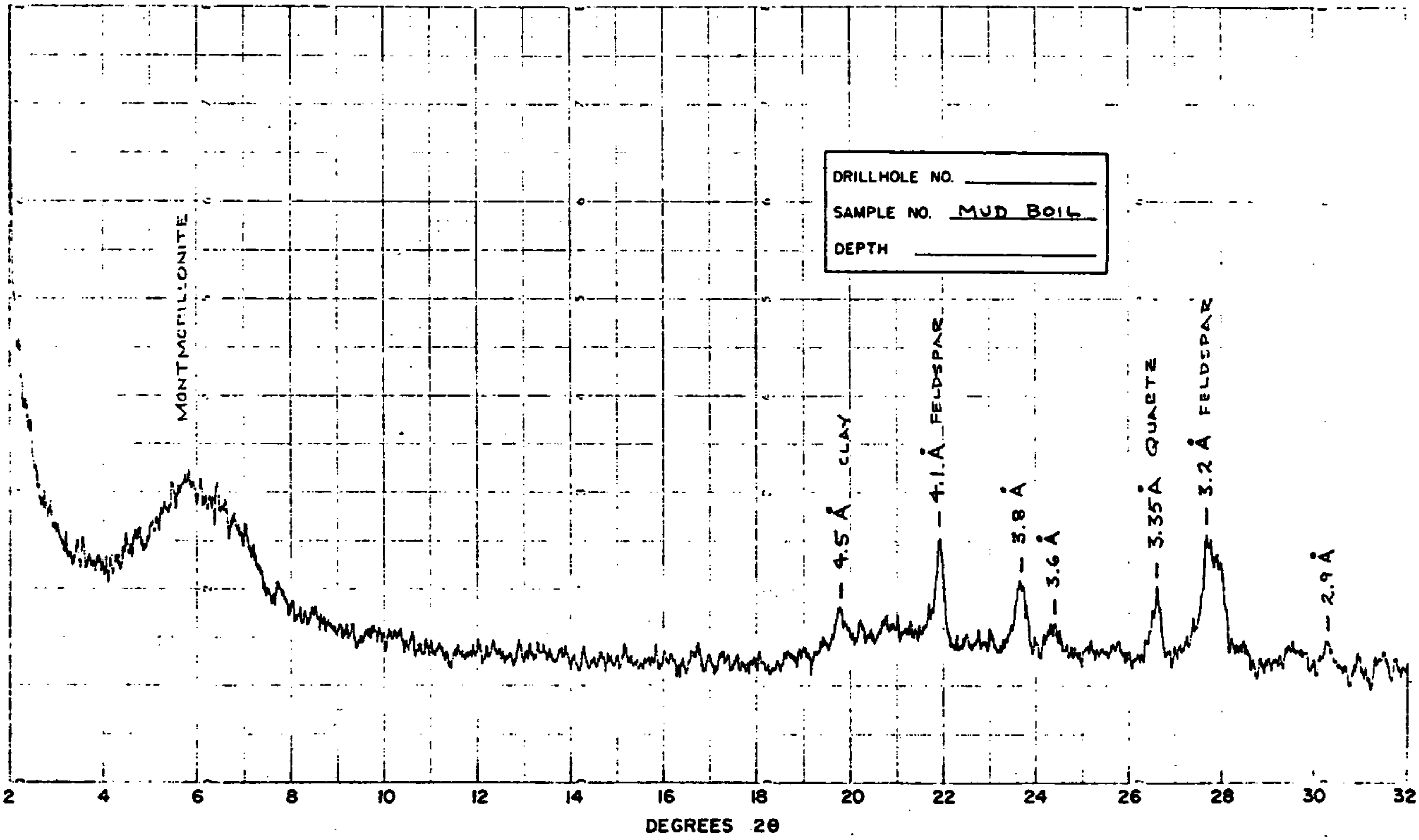
REPT. TO GOLDER ASSOC.
ACCOUNT 1319-902

HAT CREEK PROJECT

LIST OF SAMPLES RECEIVED FROM GOLDER BRAWNER + ASSOC.

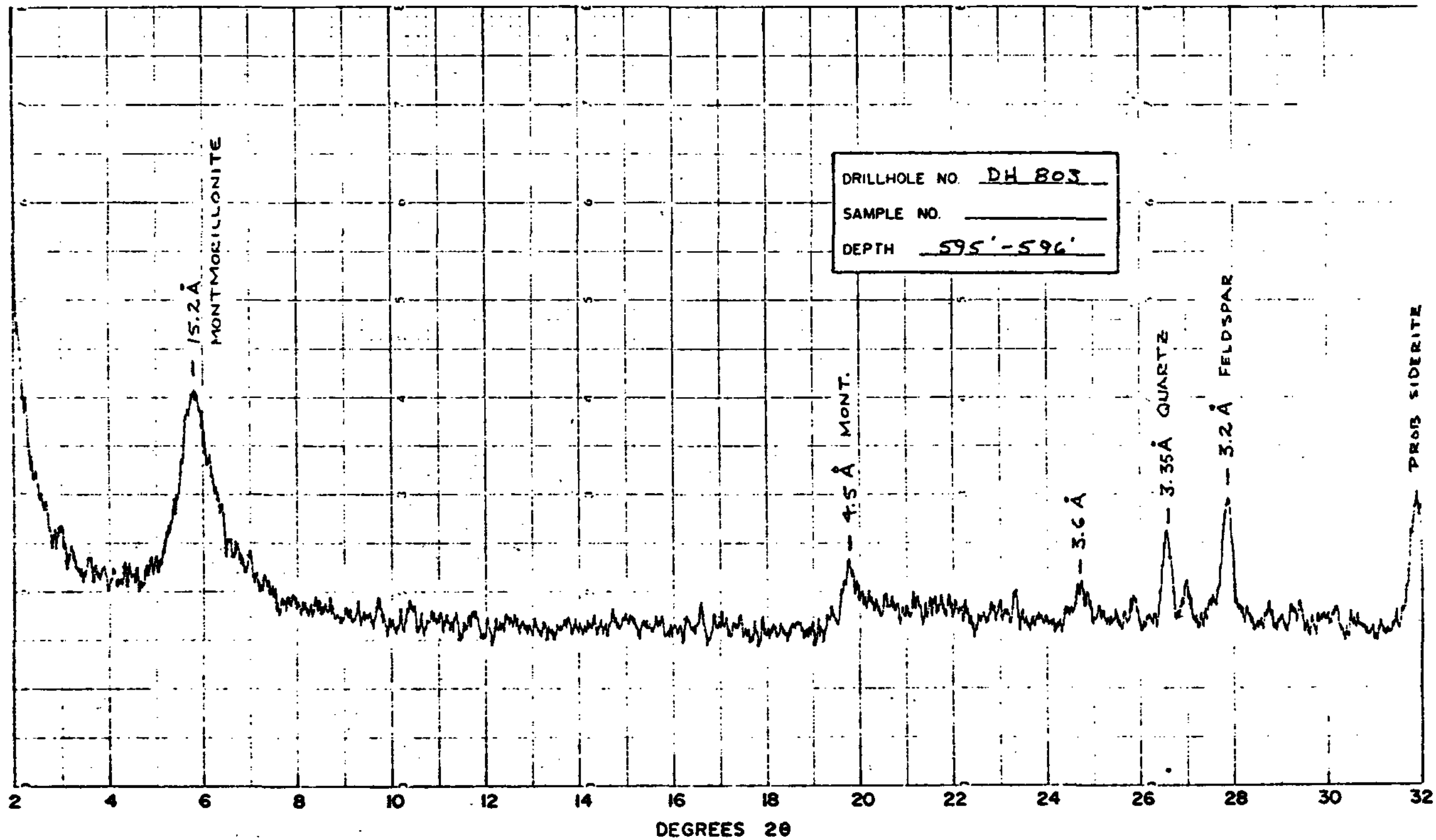
DRILL HOLE NO.	SAMPLE NO.	DEPTH	DATE REC'D	TESTING COMPLETED						
				X-RAY				CARBONATE	GLYCOL RETENTION	Na^+ (PPM)
				WET P.O.	ADPO	GPO.	POWDER			
	MUD BOIL		JUNE 24	✓	✓	✓	✓	4.0		
DH 803	NOT GIVEN	595-596	JULY 6	✓	✓	✓	✓	17.1		
DDH 804	1A	50.0'-51.7'	JULY 13	✓	✓	✓	✓	1.7		
DDH 806	7	16.8'-18.8'	JULY 13	✓	✓	✓	✓	1.3		
DDH 803	28	136.0-137.0 ~~135.0-136.0~~	JULY 15	✓	✓	✓	✓	1.7		
DDH 803	29	316.0'-317.7'	JULY 15	✓	✓	✓	✓	32.4		
DDH 805	16 GREEN / BLACK	61.5'-62.5'	JULY 15	✓	✓	✓	✓	5.3 / 1.1		
DDH 807	12	22.0'-24.0'	JULY 15	✓	✓	✓	✓	2.4		
DDH 807	14	158.3'-159.5	JULY 15	✓	✓	✓	✓	1.7		

GEOTECHNICAL LABORATORY
UNIV. OF WESTERN ONTARIO
R. M. Quigley
July 23/76



X-RAY DIFFRACTION TRACES OF WHOLE SOIL POWDERS FROM HAT CREEK.

Geotechnical Laboratory
The Univ. of Western Ontario



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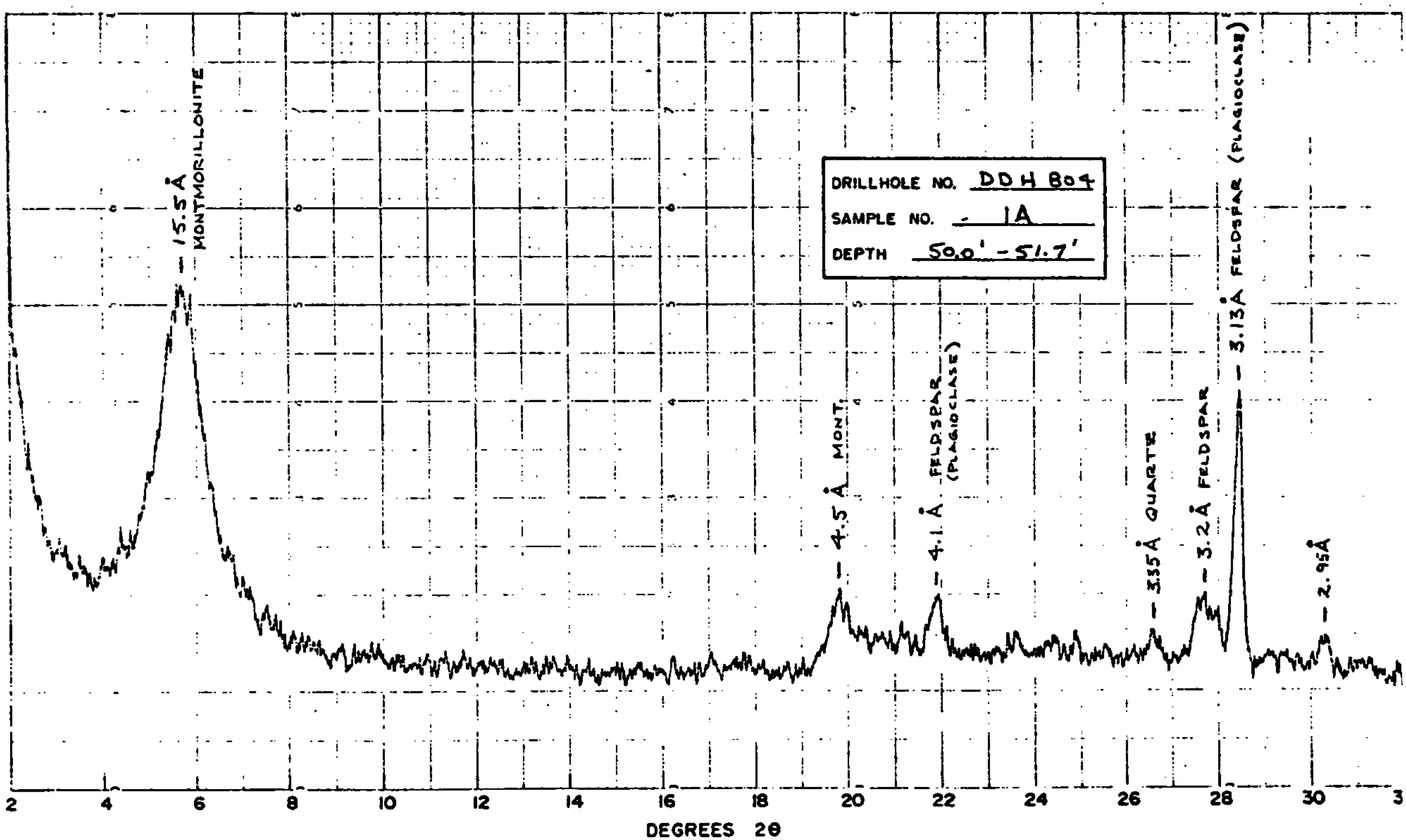

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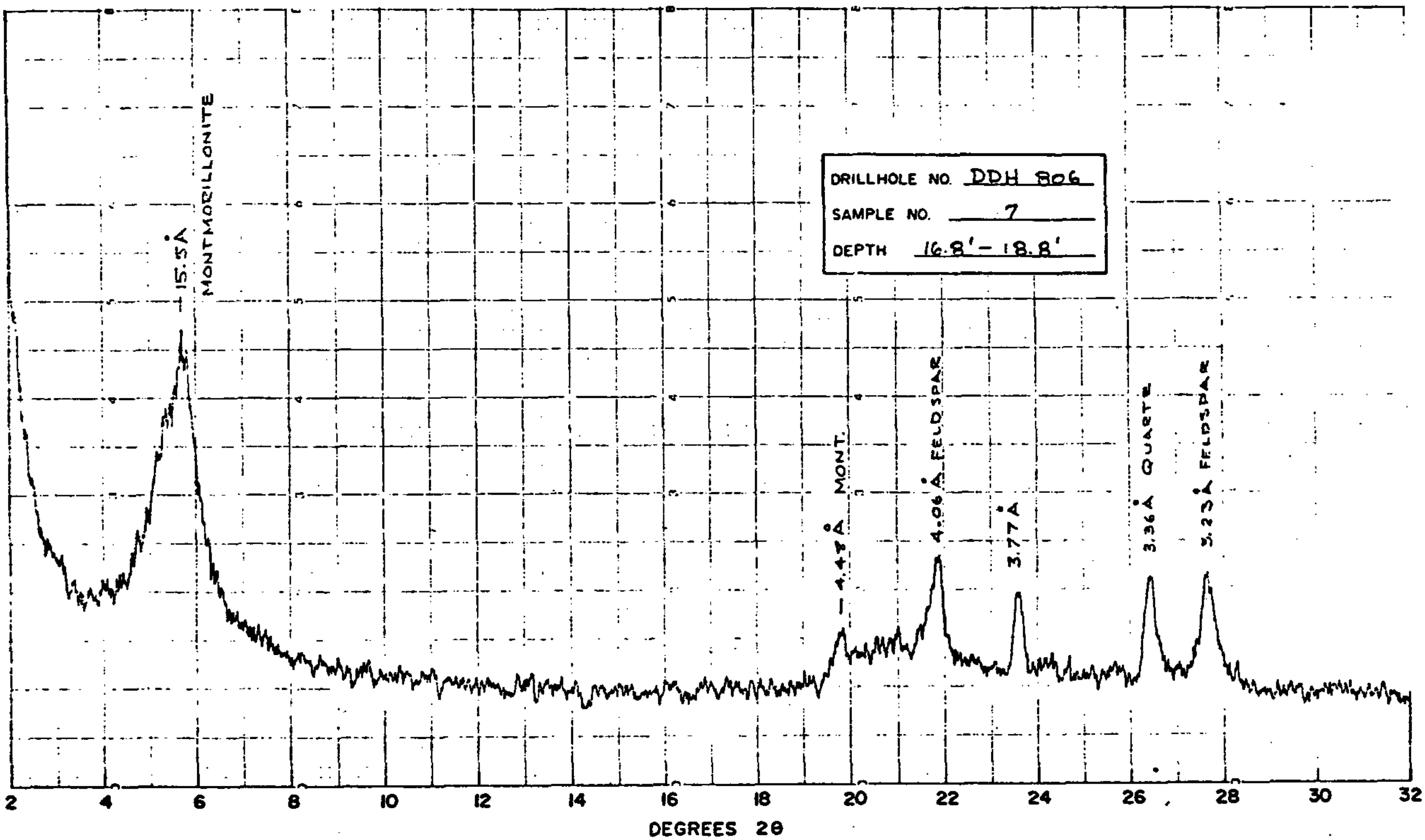

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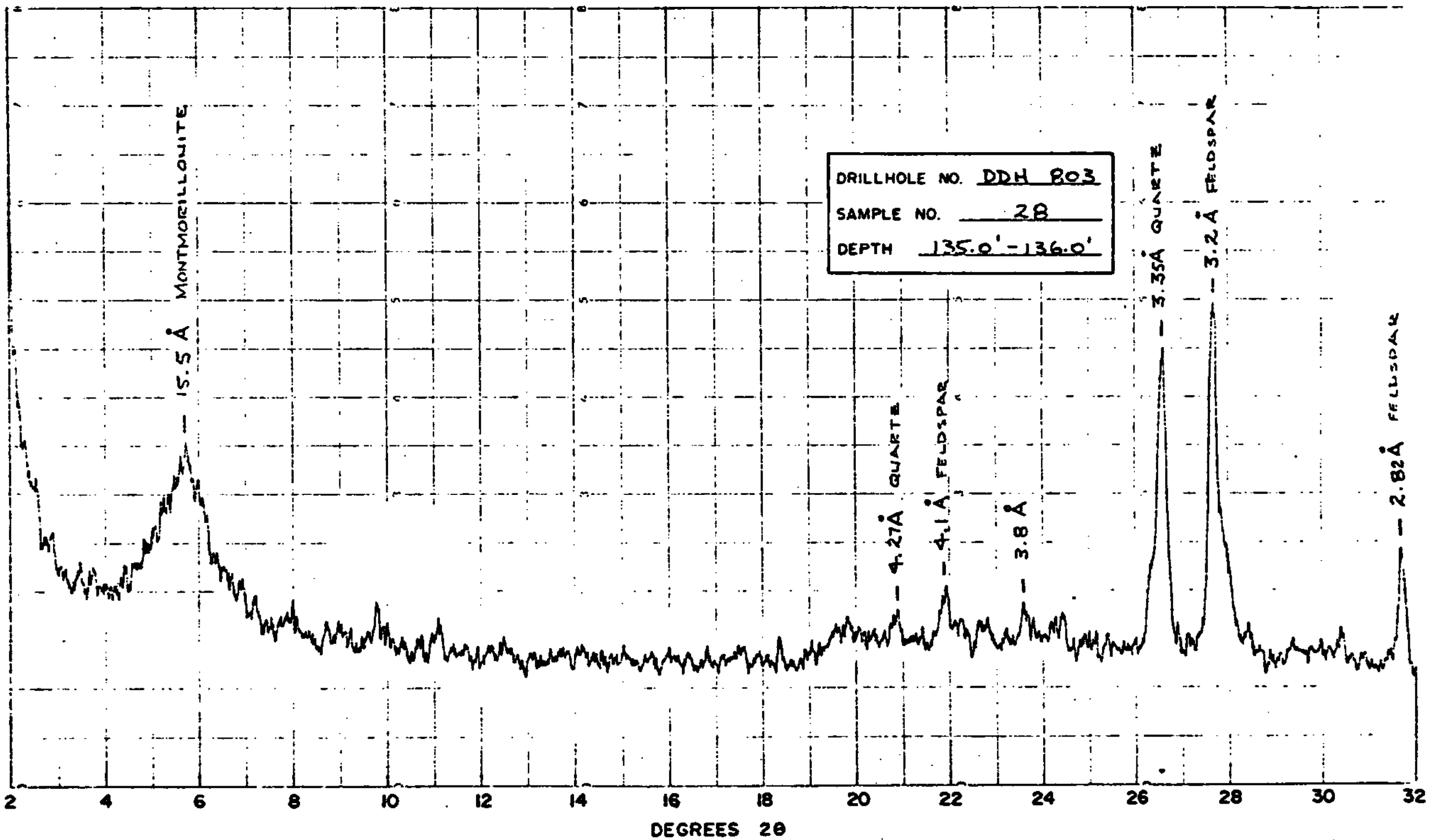

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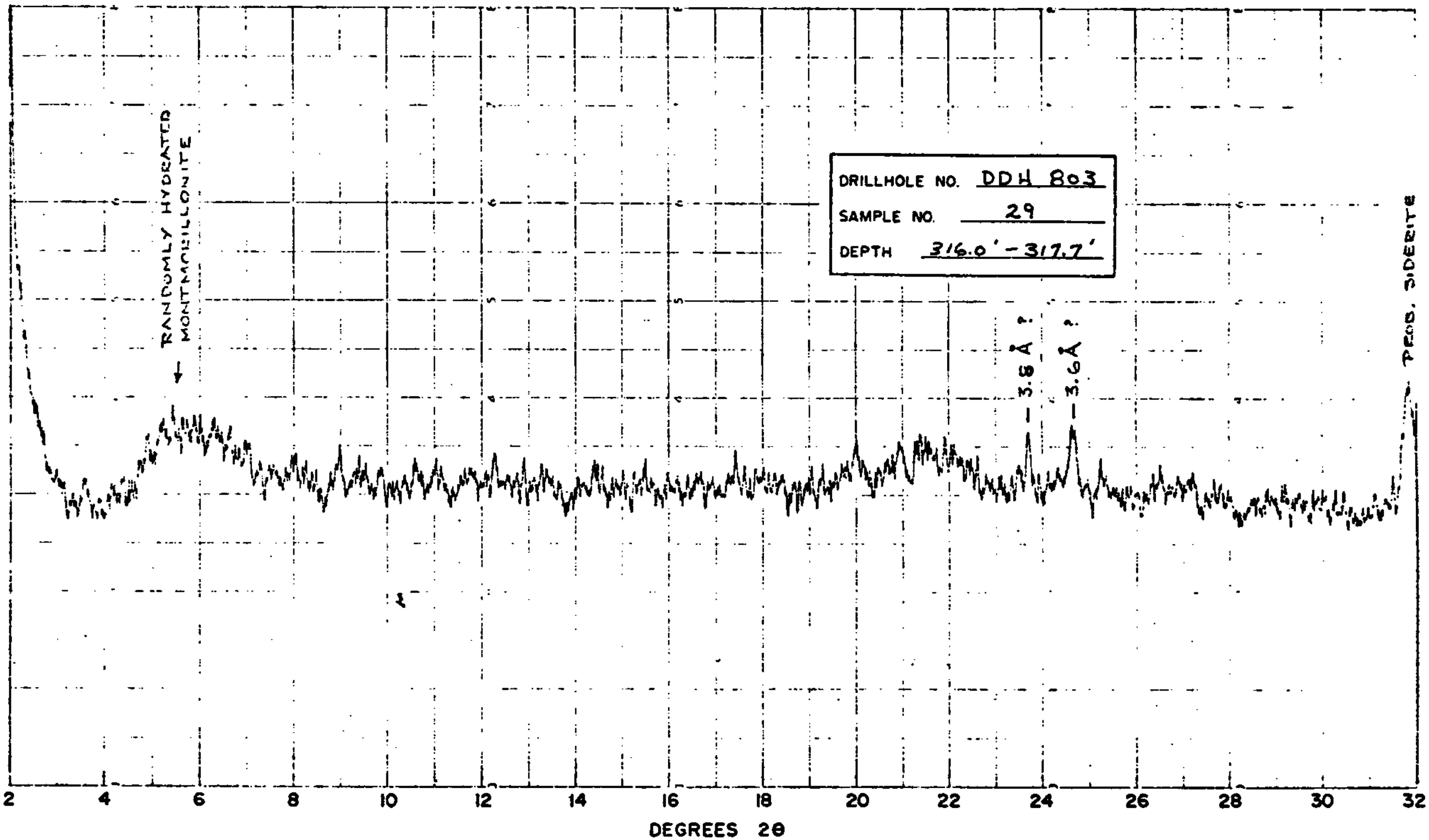

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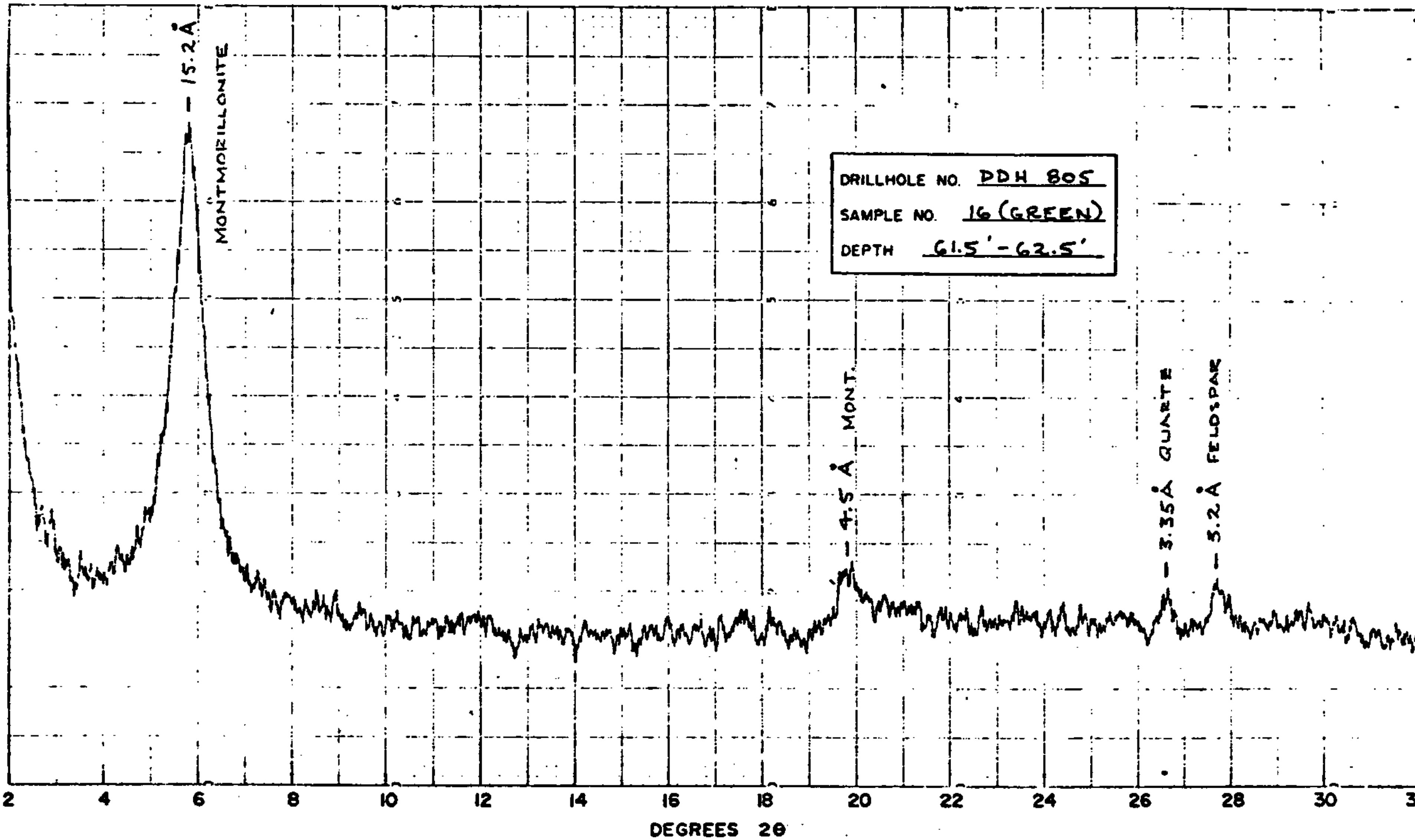

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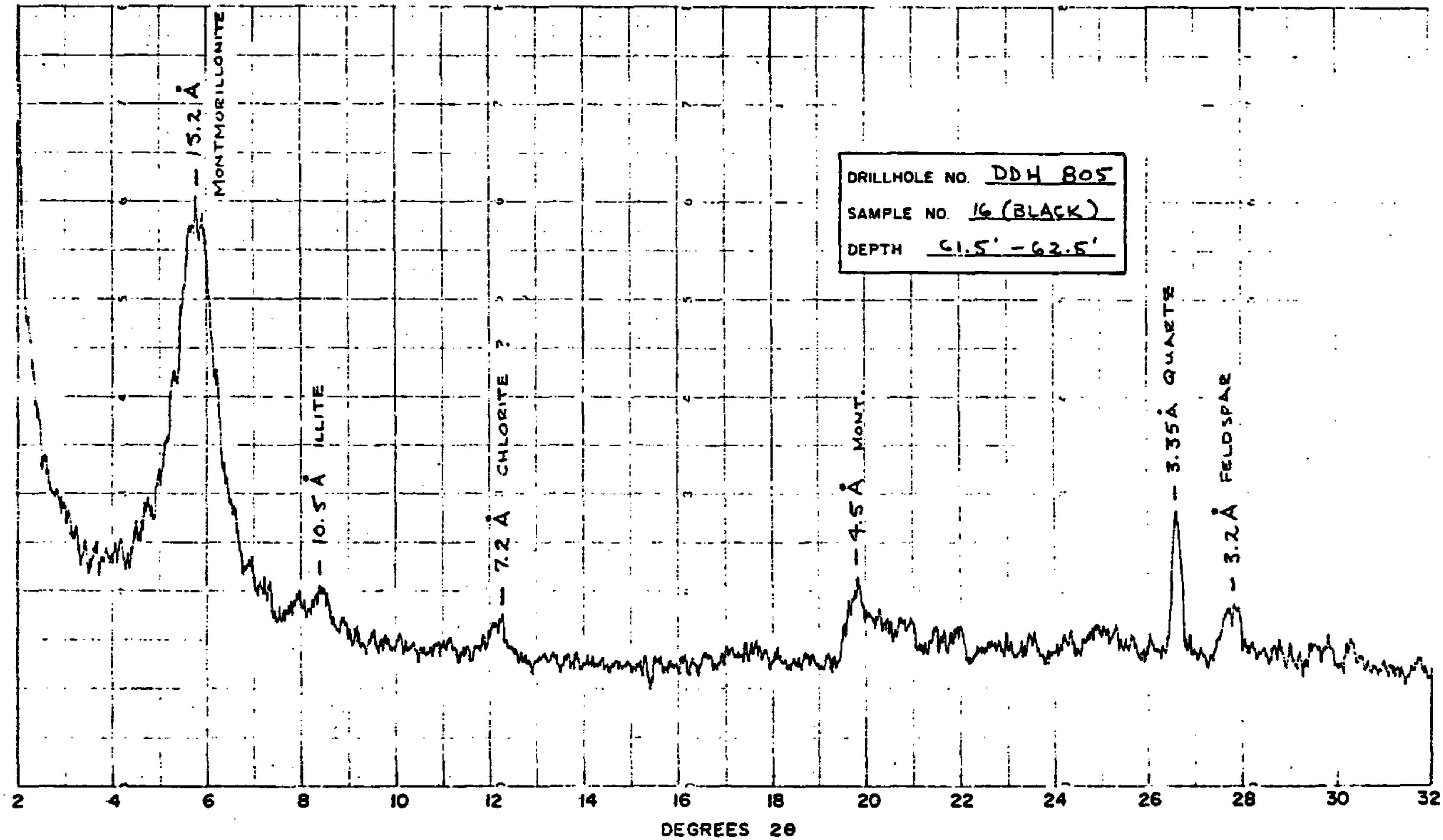

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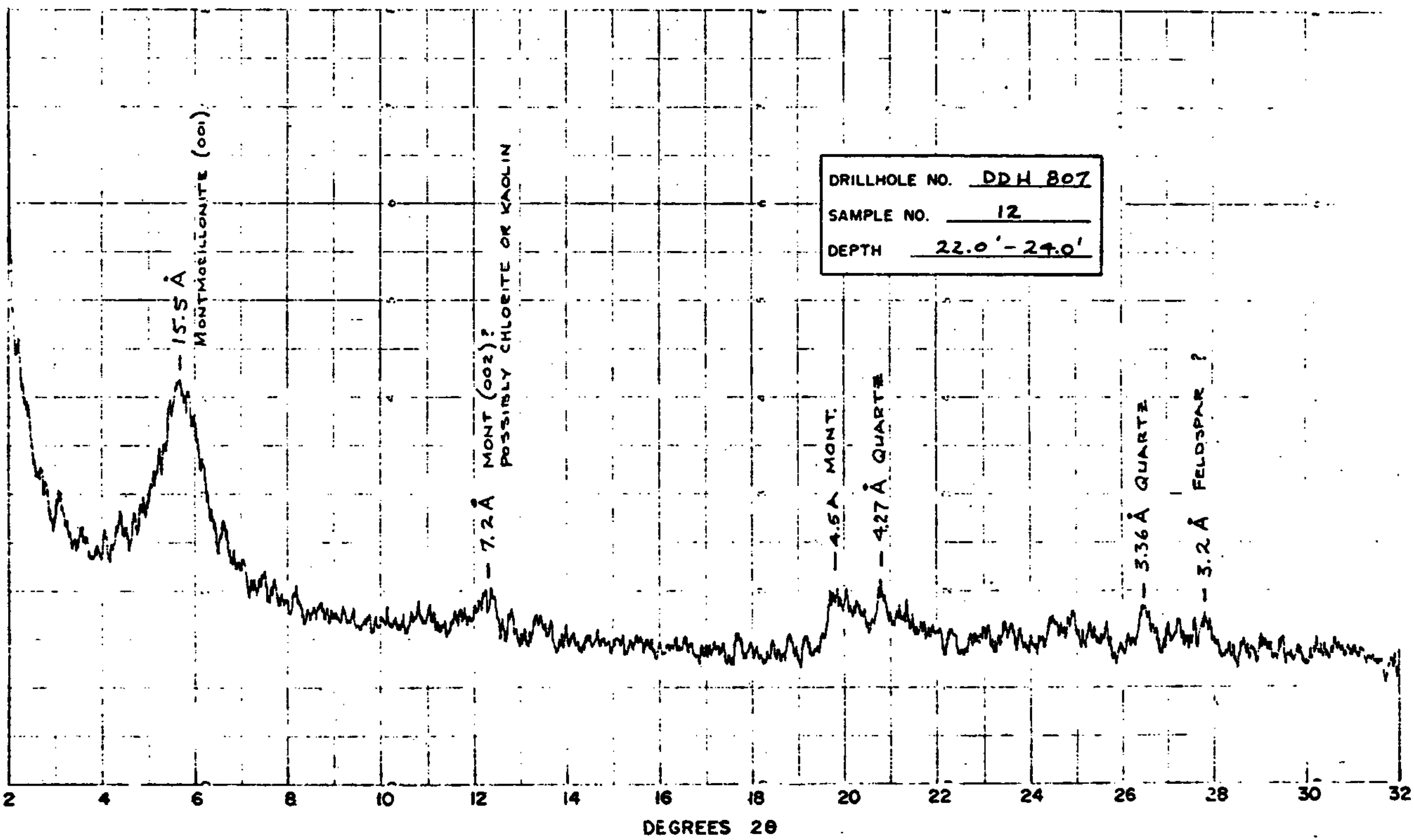

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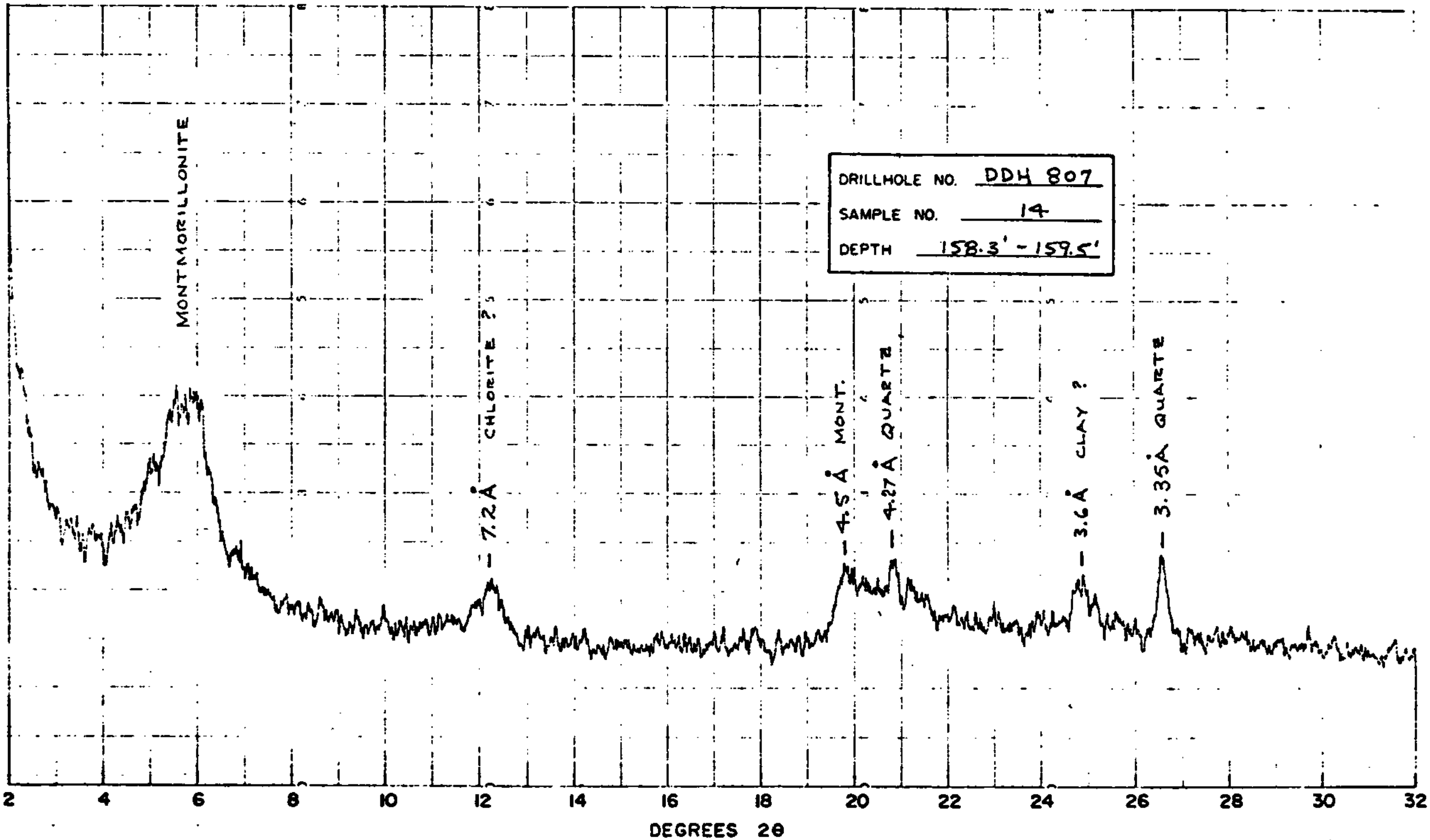

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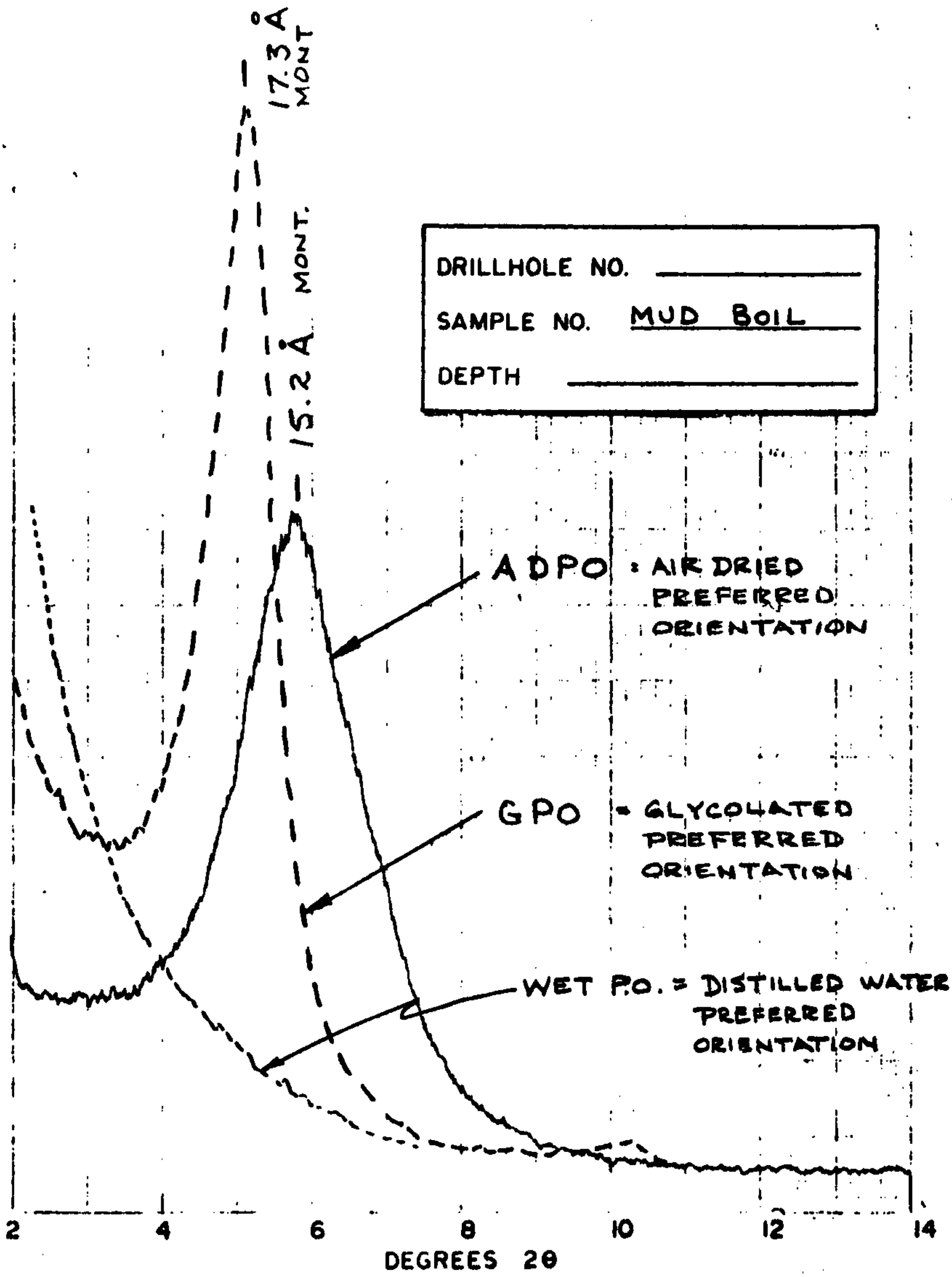

X-RAY DIFFRACTION TRACES OF 2 μ, PREFERRED ORIENTED SPECIMENS FROM HAT CREEK.

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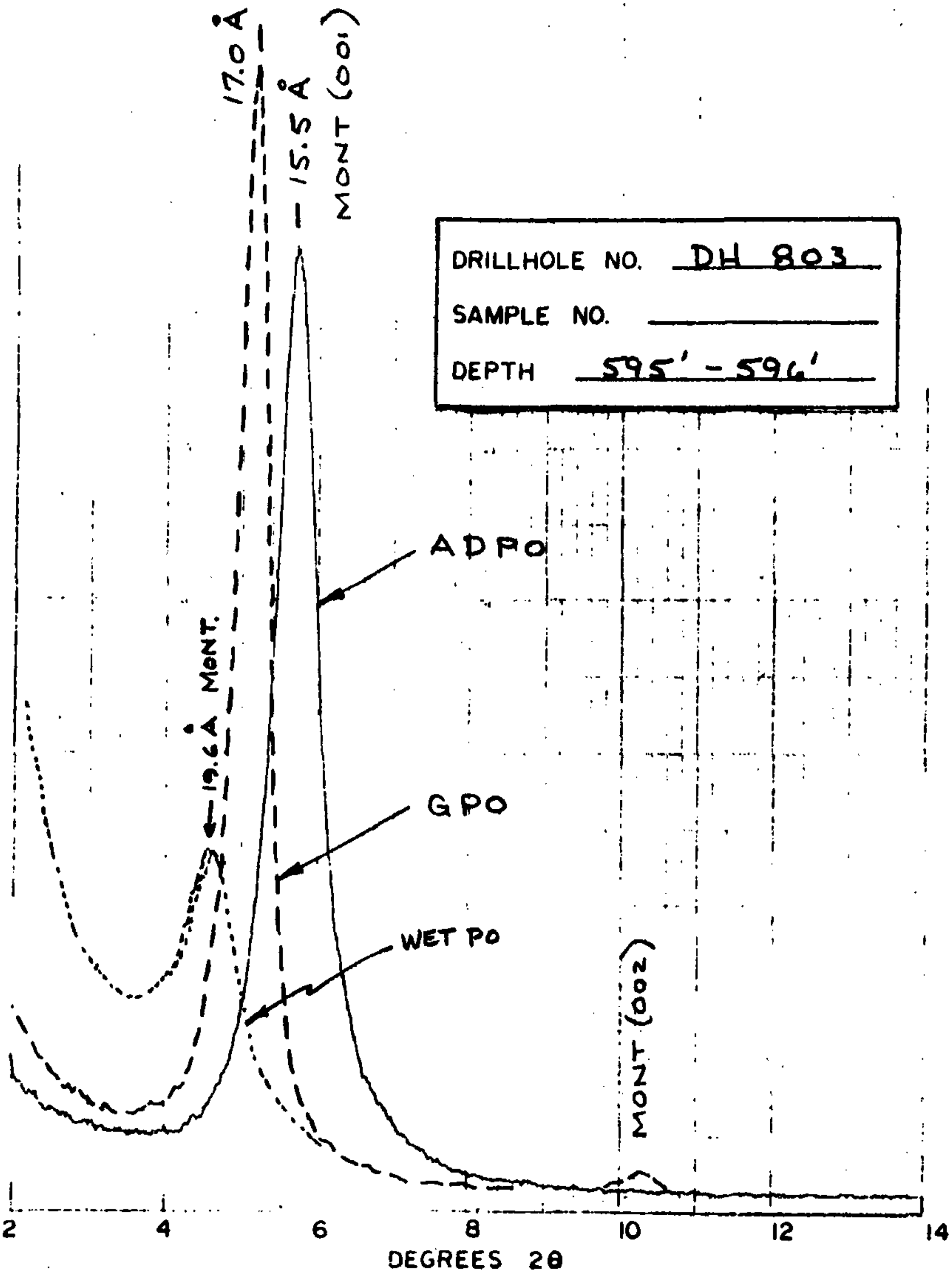

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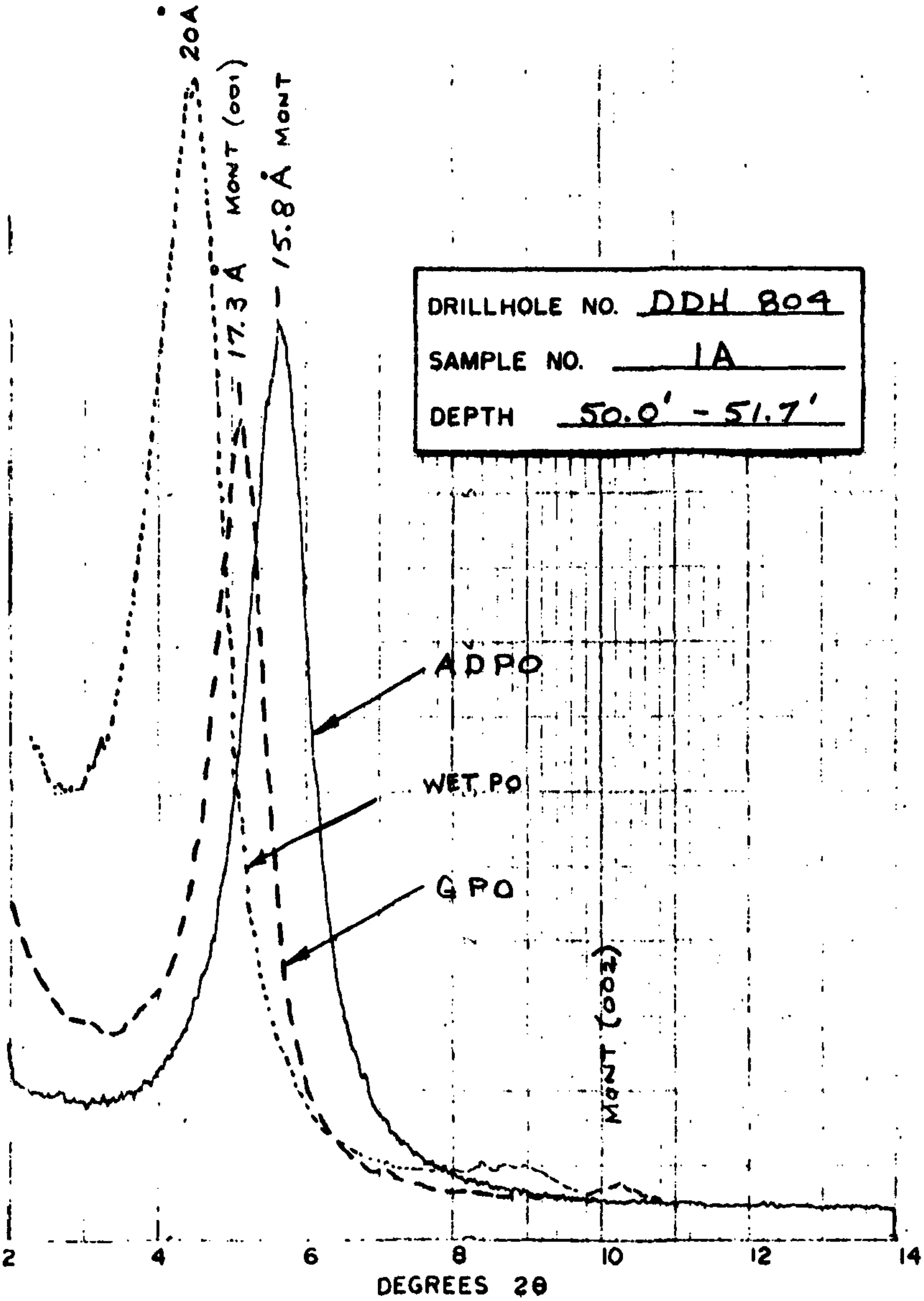

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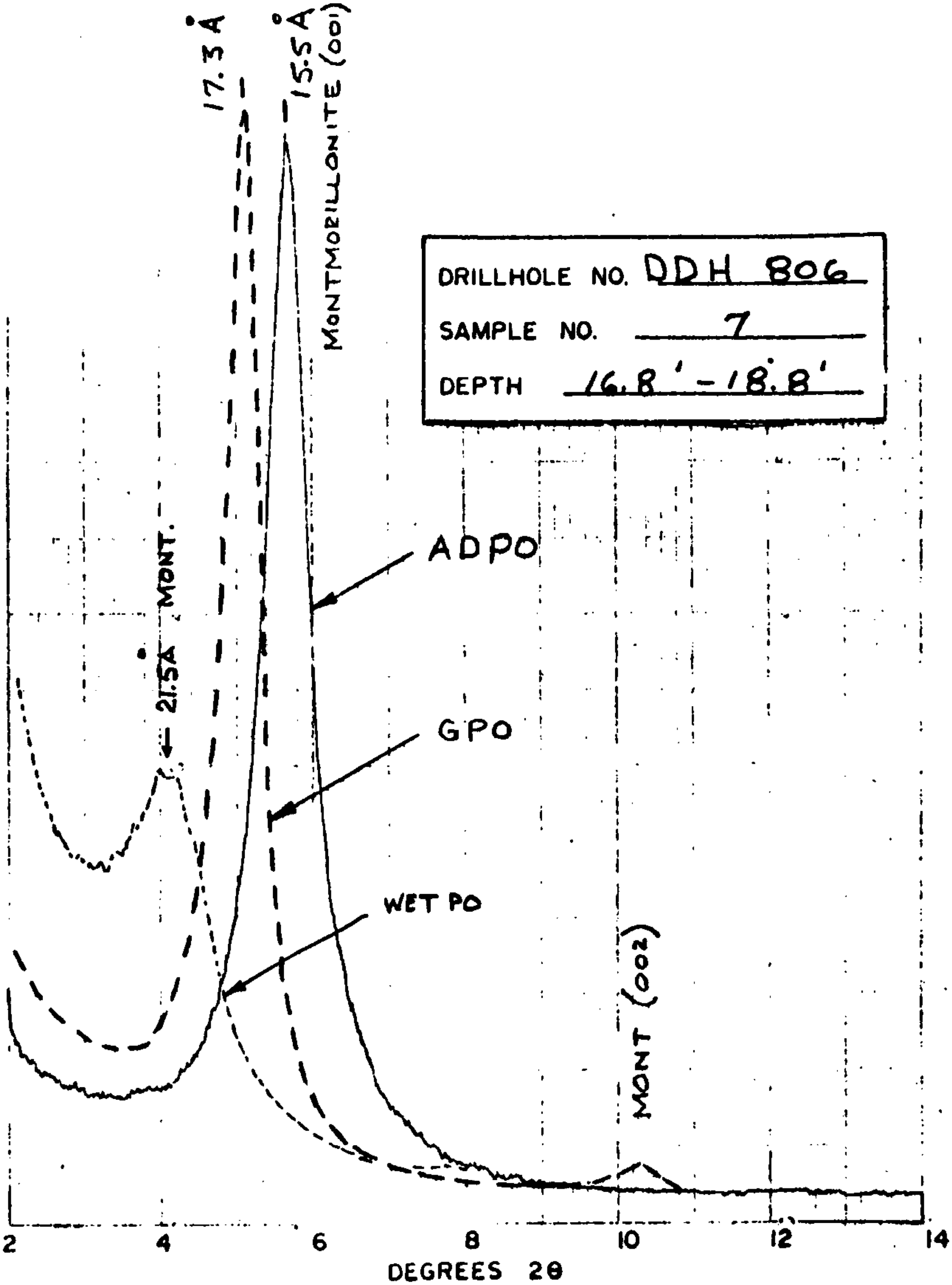

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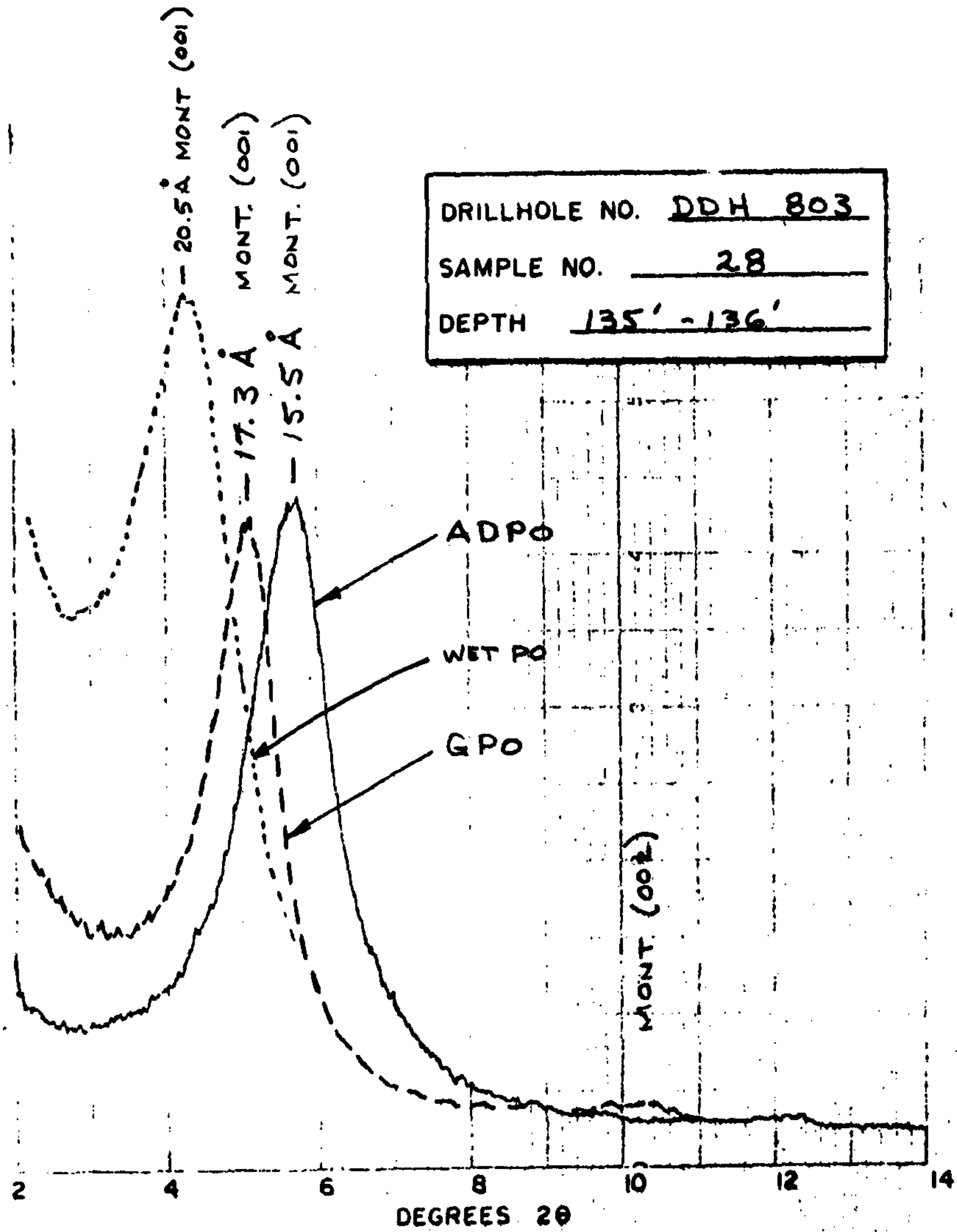

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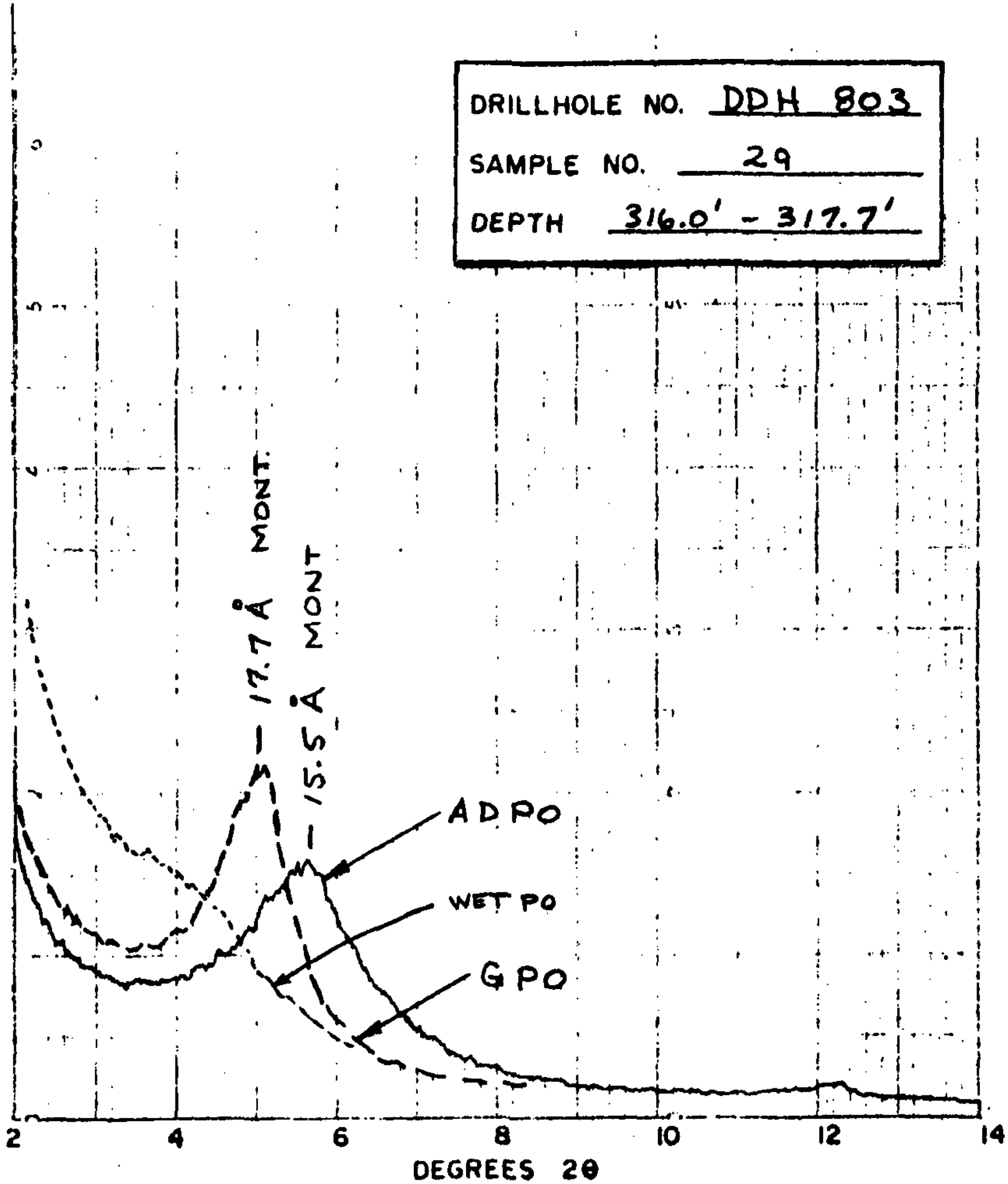

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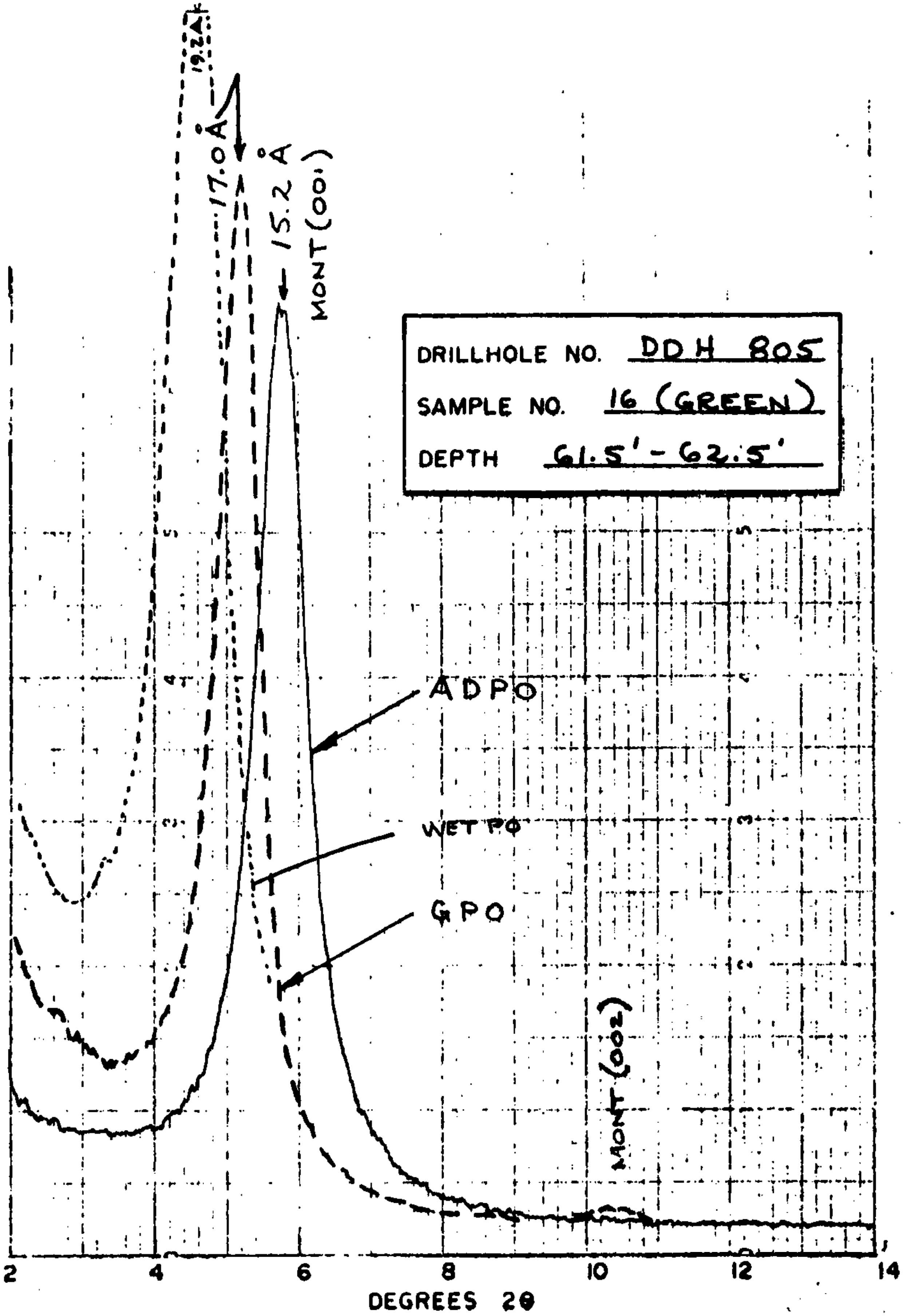

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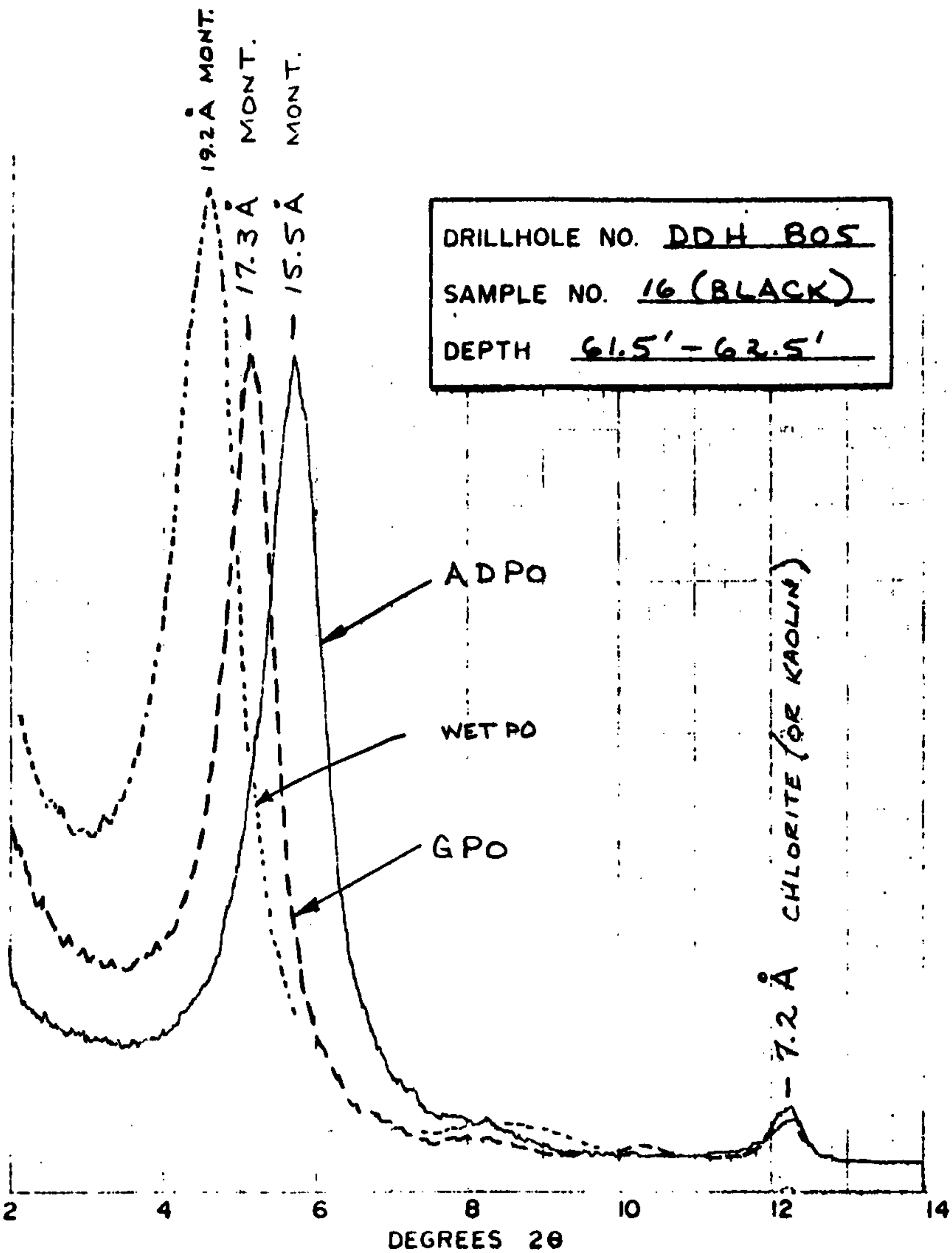

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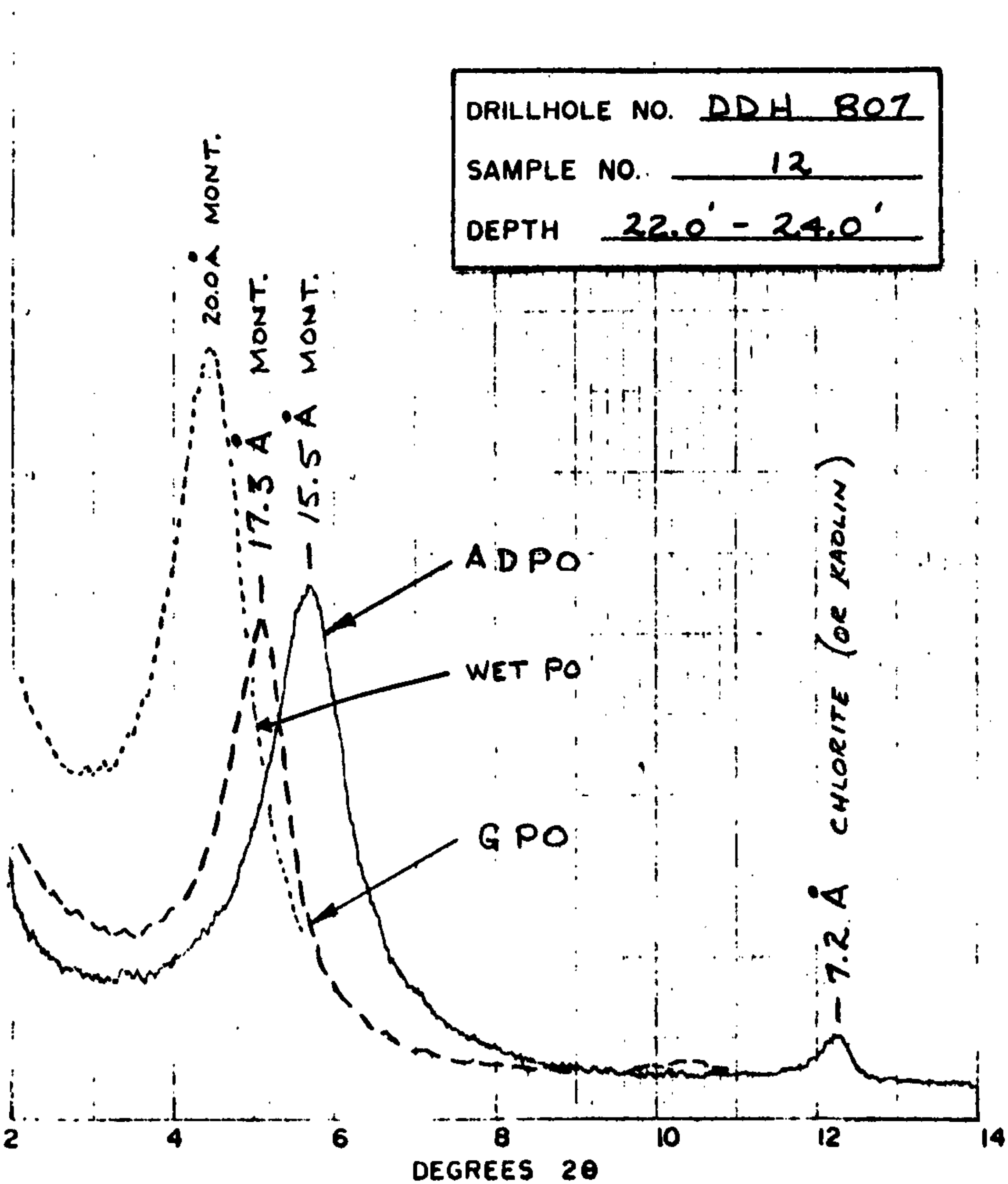

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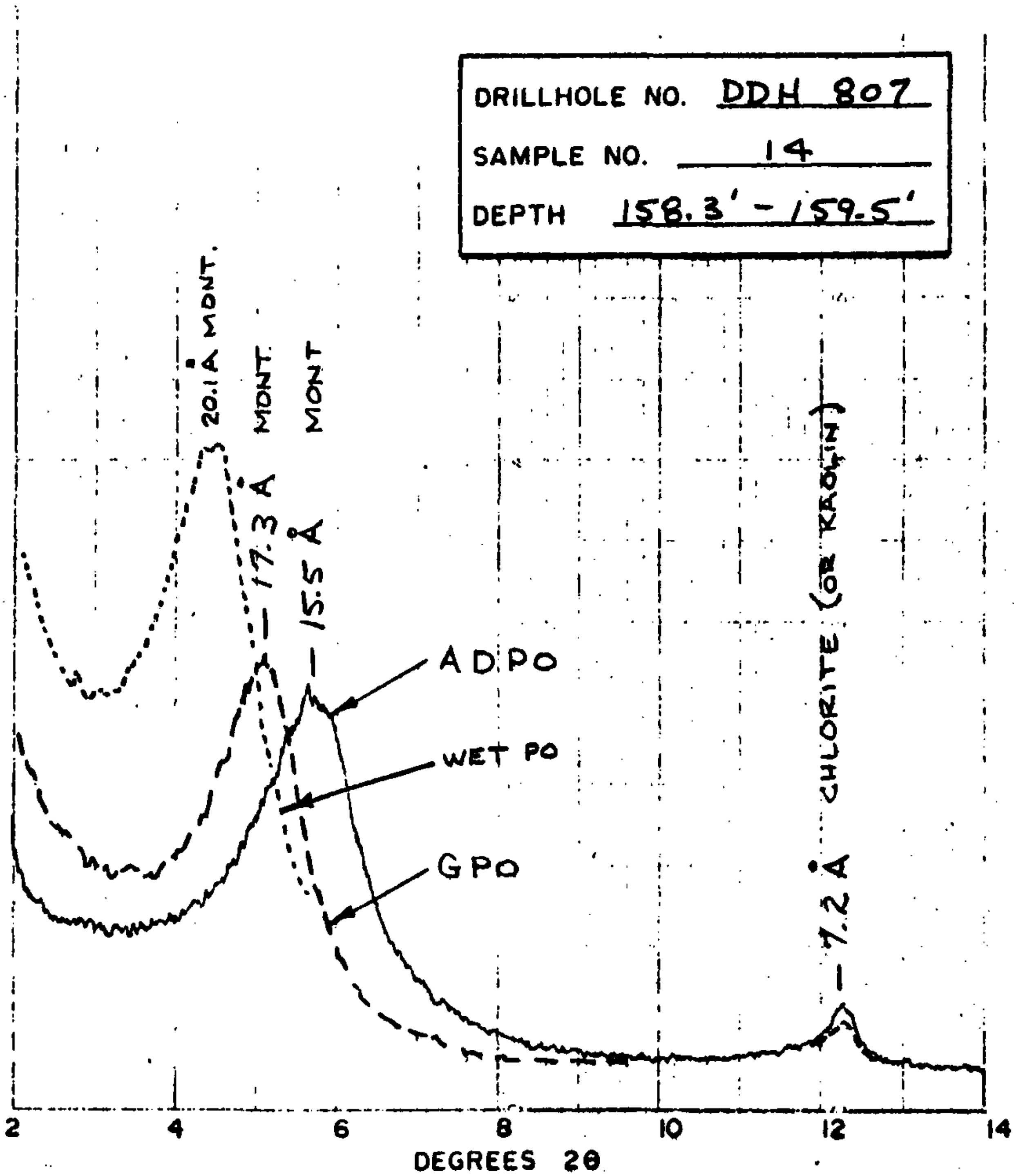


X-RAY DIFFRACTION TRACES OF 2μ, PREFERRED ORIENTED SPECIMENS FROM HAT CREEK.

Geotechnical Laboratory
The Univ. of Western Ontario

The University of Western Ontario

Faculty of Engineering Science
London, Canada
N6A 5B9

August 13, 1976

Mr. G. Rawlings
Golder, Brawner & Associates Ltd.
224 West 8th Avenue
Vancouver, B.C.
V5Y 1N5

Dear Mr. Rawlings:

Report #2
Hat Creek Project - Mineralogical Analyses
August 13, 1976

We have completed x-ray and carbonate analyses on 9 of the 25 samples received on August 3, 1976 from Mr. H. Hawson. The results, which are all for B.H. 74-28, are reported in our Report #2 attached.

The delay in processing has been caused by the indurated nature of many of the samples making disaggregation into finer fractions very difficult.

The current suite of samples from Borehole 74-28 shows a highly variable carbonate content, most of which appears to be an impure siderite (see Table). Where siderite is of lesser importance, the silicate minerals quartz and feldspar become the dominant non-clay mineral components.

In the <2μ fraction, montmorillonite dominates, yielding the very strong (001) peaks shown in the traces for the preferred orientation samples.

Yours sincerely,

R.M. Quigley

R.M. Quigley, P.Eng.
Professor and Head
Geotechnical Section

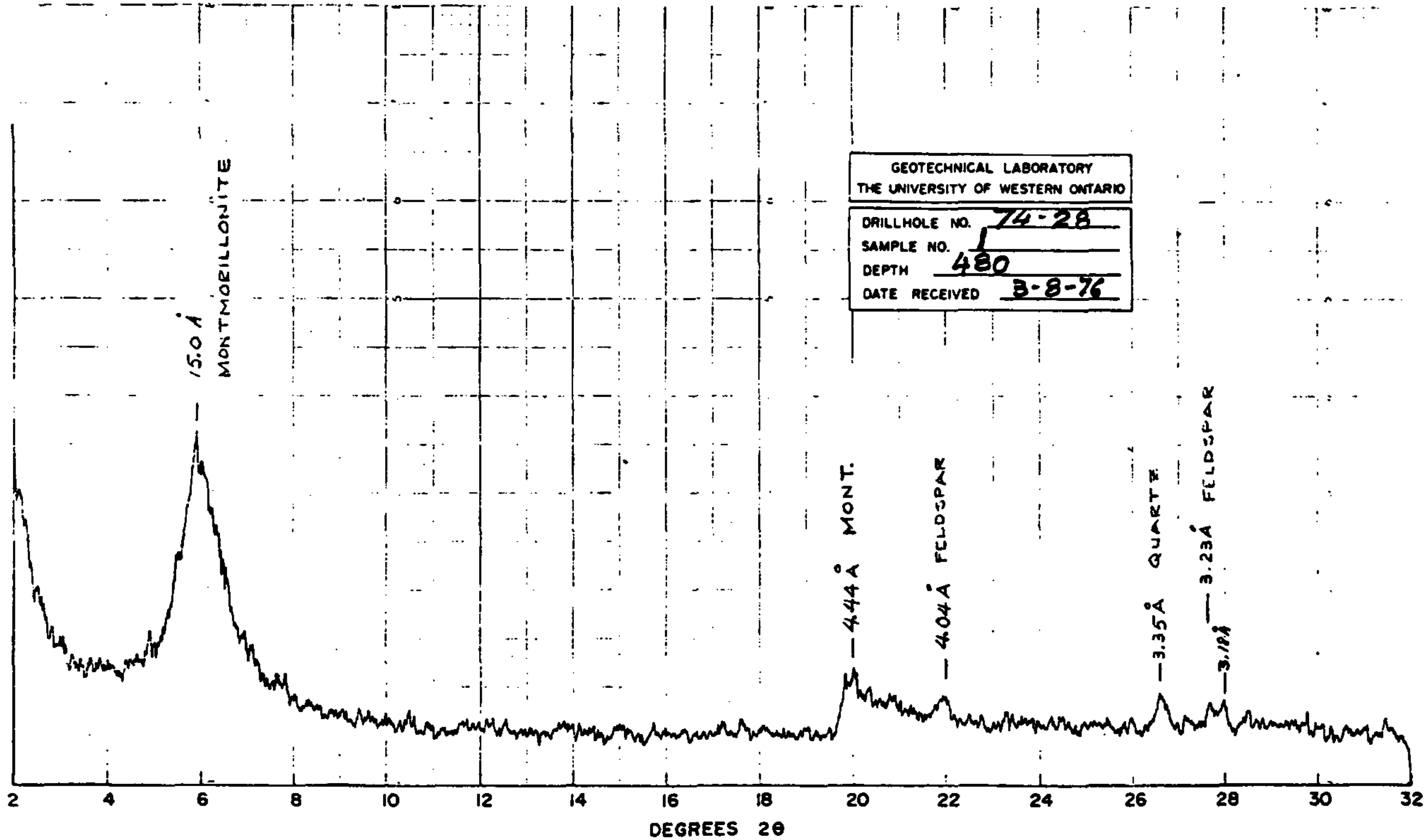
RMQ/jl
Attach.
cc. Mr. H. Hawson

HAT CREEK PROJECT
LIST OF SAMPLES RECEIVED FROM GOLDER BRAWNER & ASSOCIATES

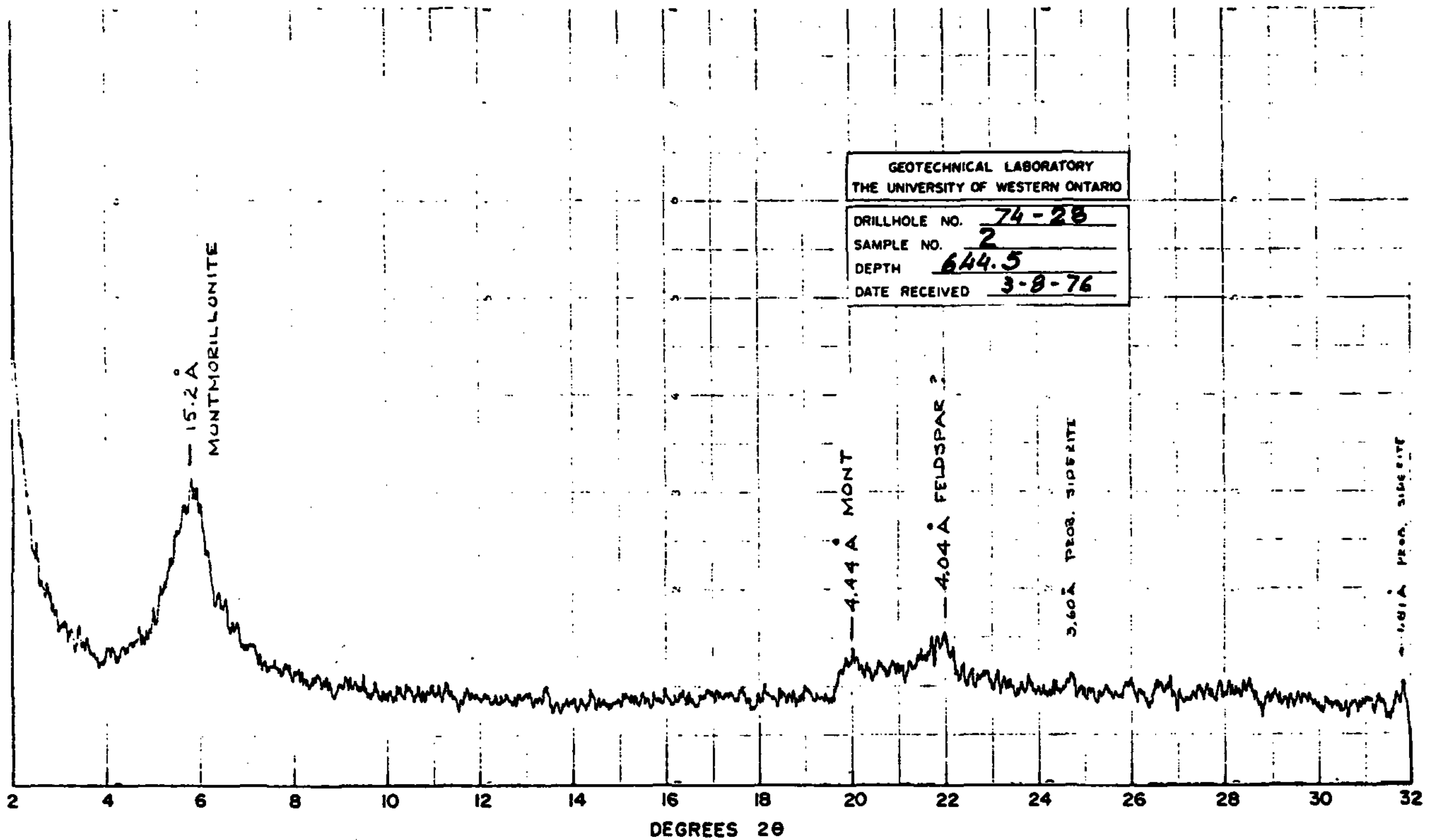
GEOTECHNICAL LABORATORY
THE UNIVERSITY OF WESTERN ONTARIO

Drill Hole No.	Sample No.	Depth (Feet)	Date Received	Testing Completed						
				X-ray				Carbonate (%)	Glycol Retention (mg/g)	Na^+ (PPM)
				Wet P.O.	ADPO	GPO	Powder			
74-28	1	480	3-8-76	✓	✓	✓	✓	2.0		
74-28	2	644.5	3-8-76	✓	✓	✓	✓	6.4		
74-28	3	738	3-8-76	✓	✓	✓	✓	7.5		
74-28	4	763	3-8-76	✓	✓	✓	✓	31.6		
74-28	5	767.5	3-8-76	✓	✓	✓	✓	26.5		
74-28	6	789.5	3-8-76	✓	✓	✓	✓	44.3		
74-28	7	451	3-8-76	✓	✓	✓	✓	12.9		
74-28	8	537	3-8-76	✓	✓	✓	✓	2.7		
74-28	9	588	3-8-76	✓	✓	✓	✓	1.5		

REPORT #2
AUG. 13, 1976
R.M. Quigley



X-RAY DIFFRACTION TRACES OF WHOLE SOIL POWDERS FROM HAT CREEK.



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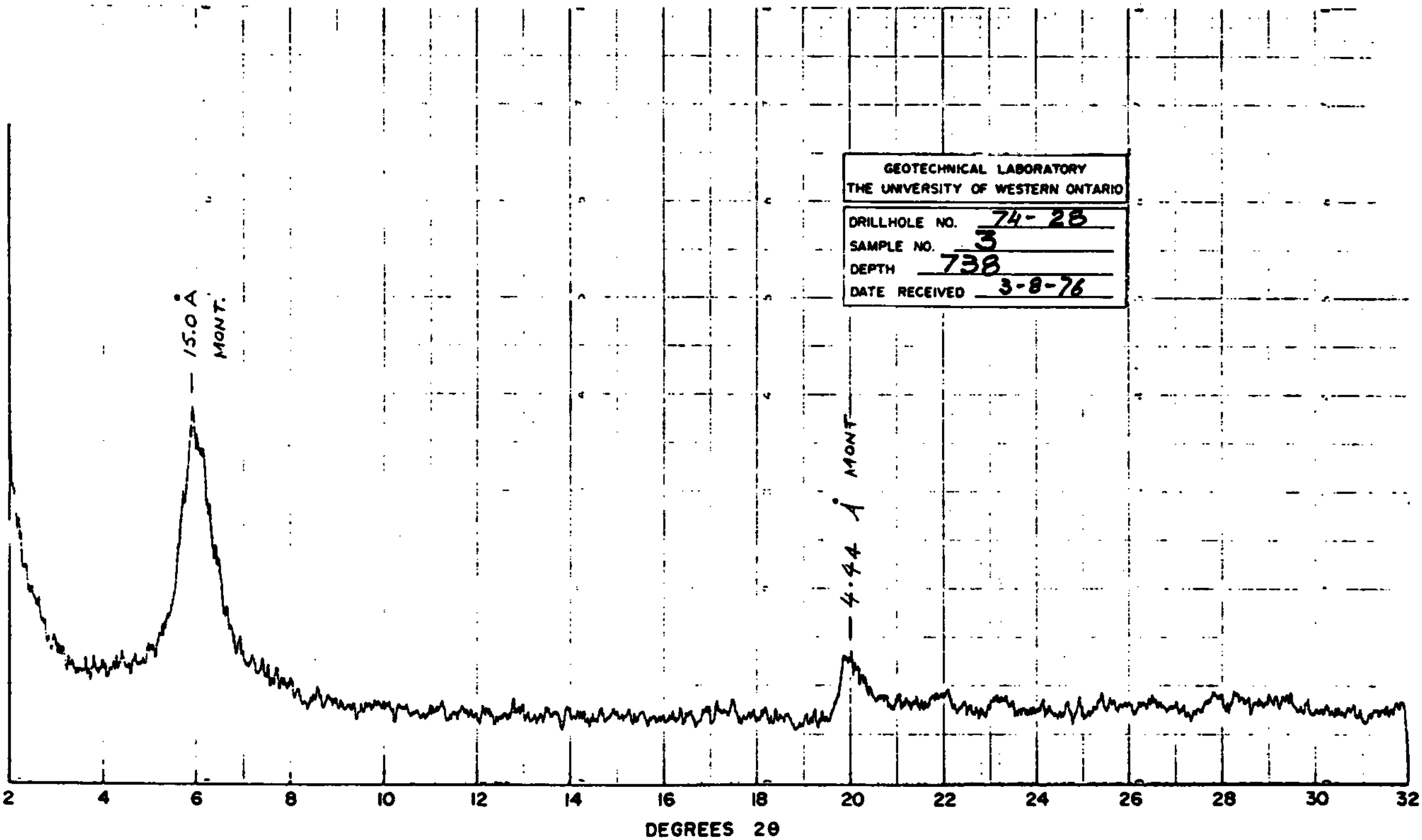

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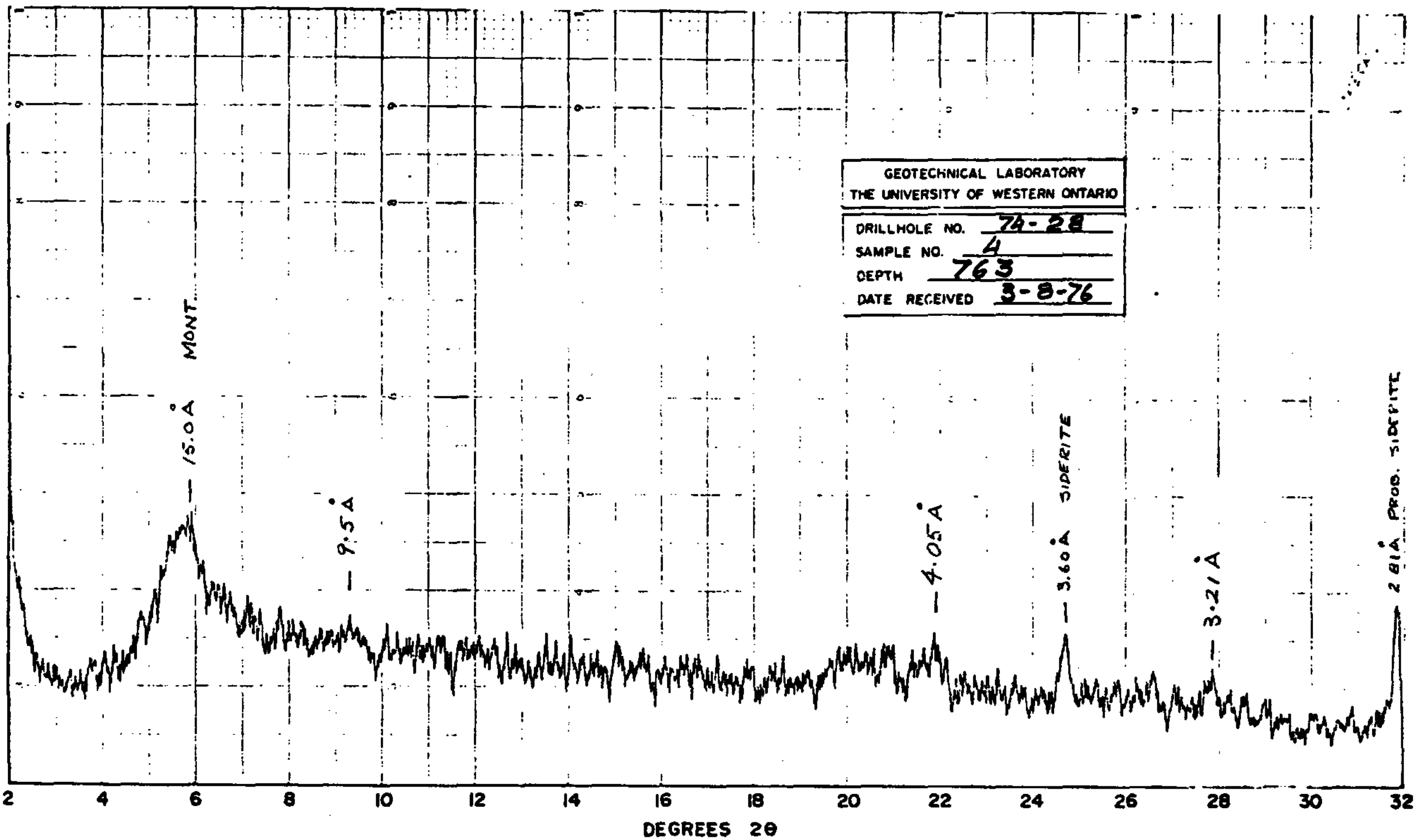

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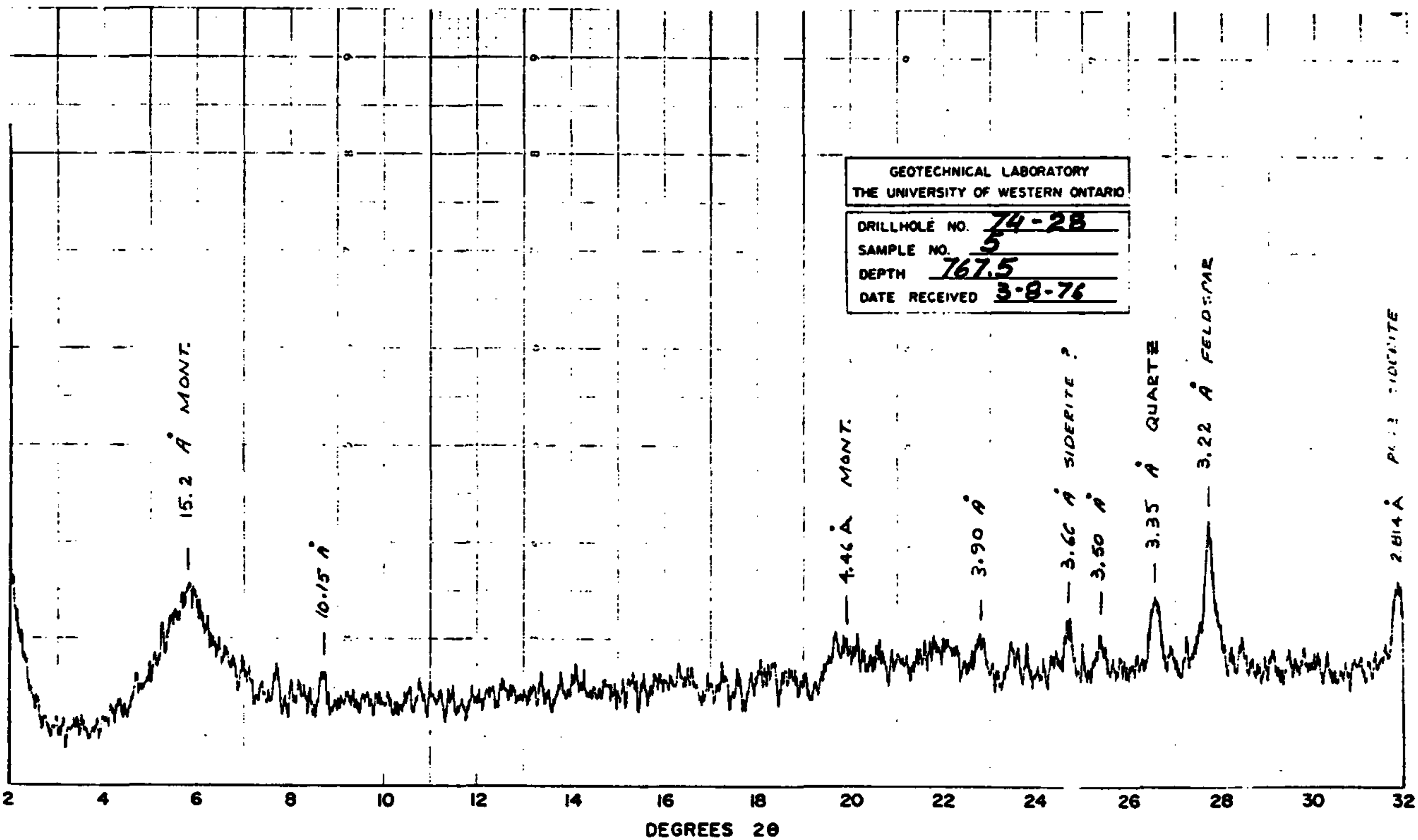

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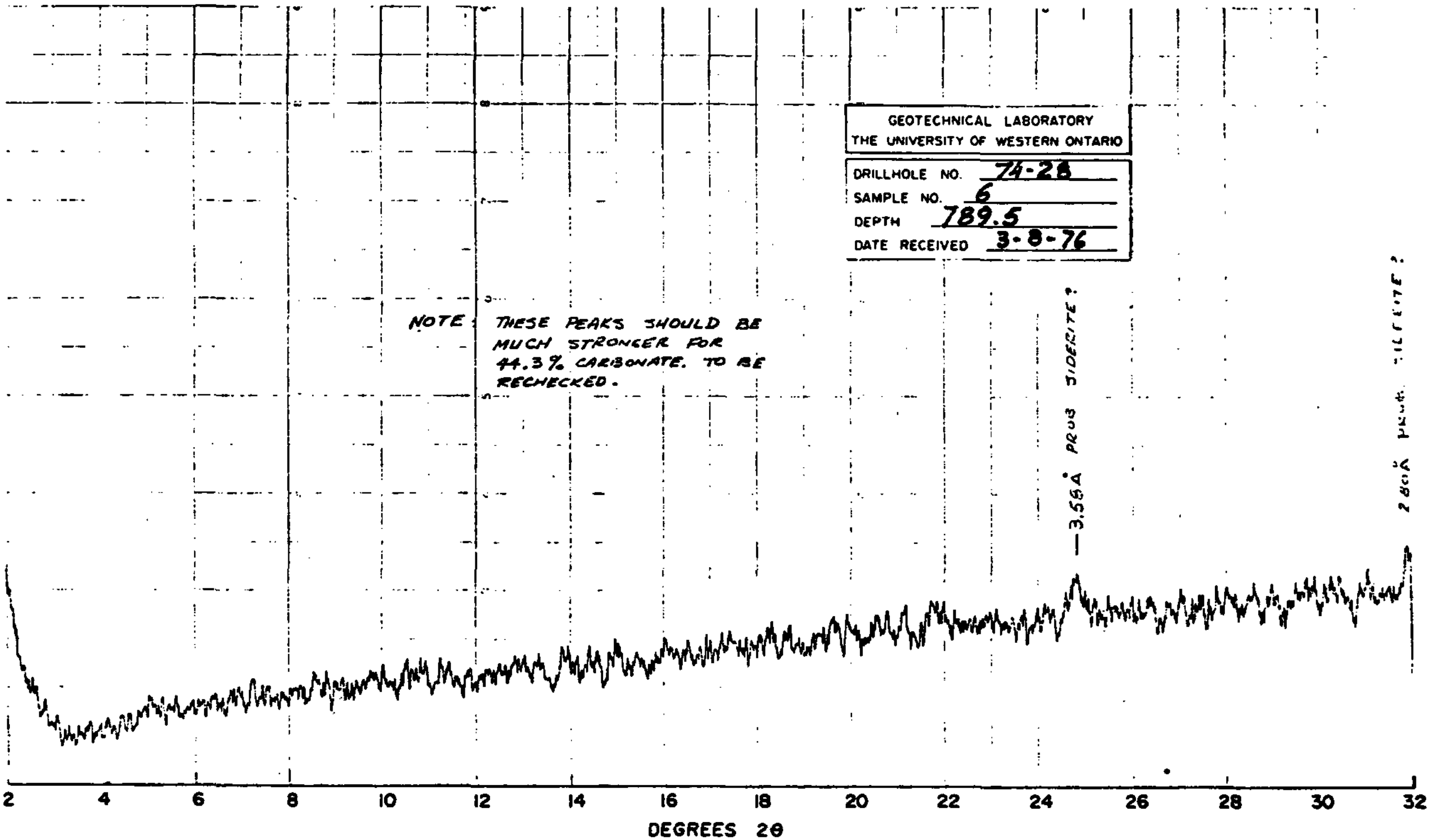

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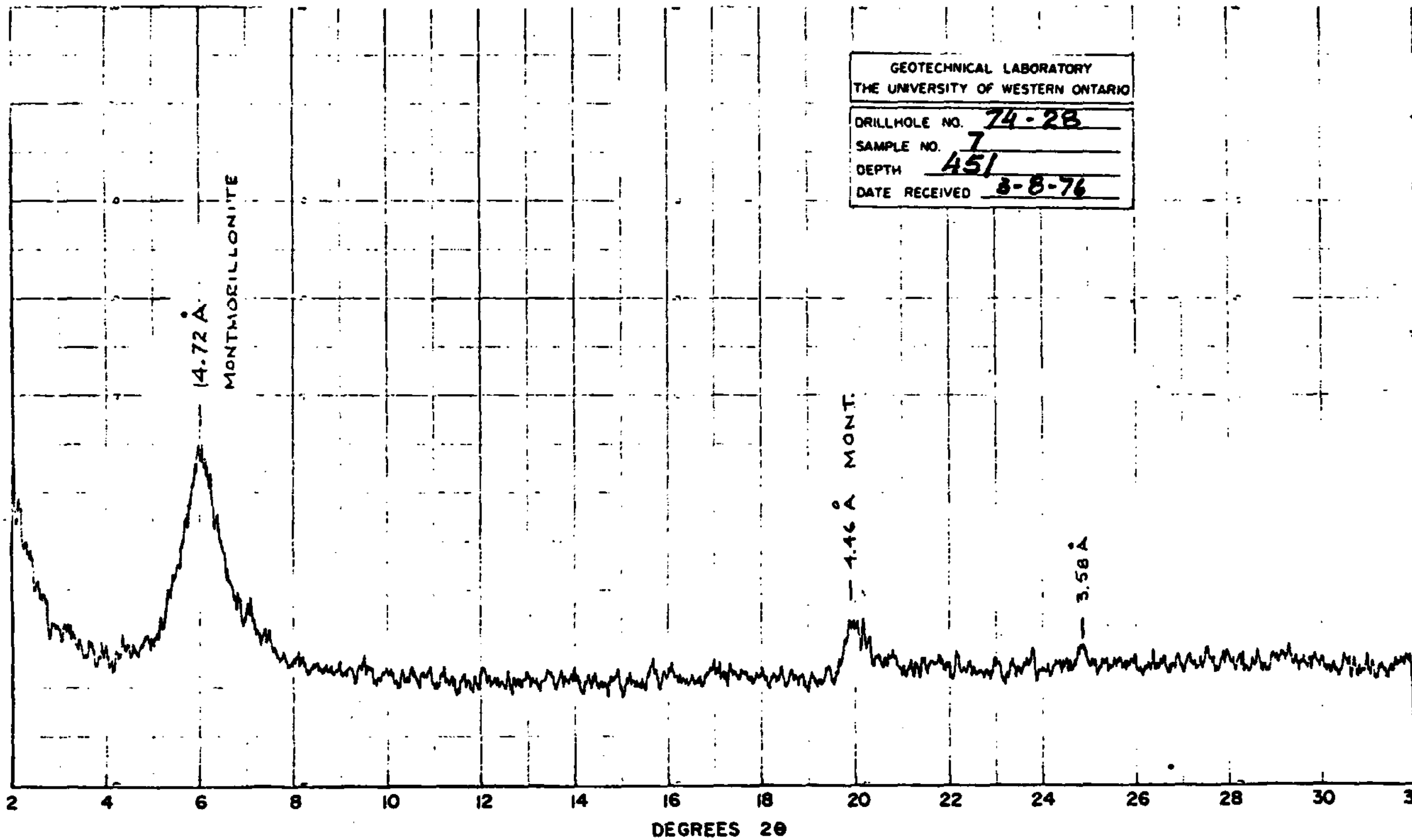

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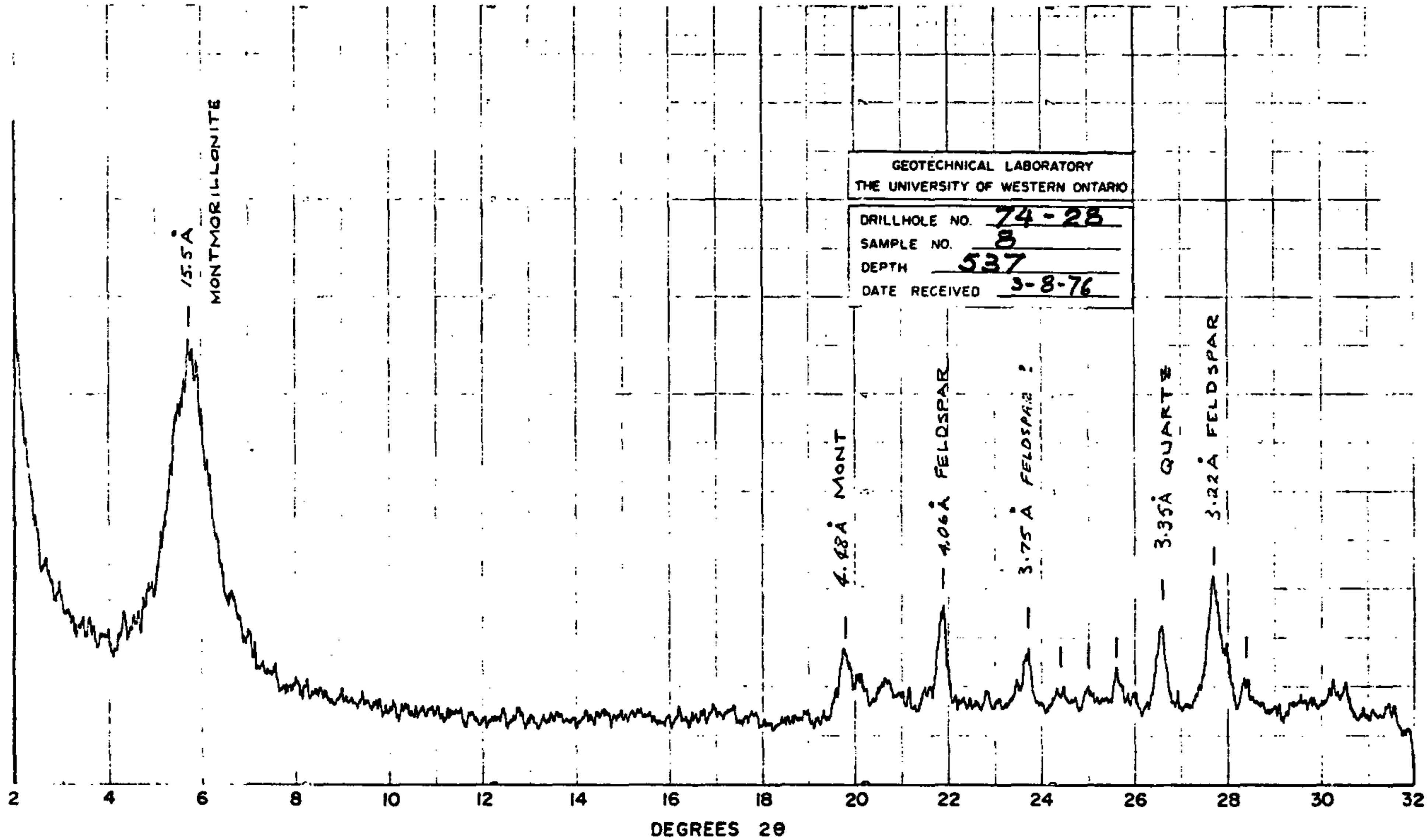

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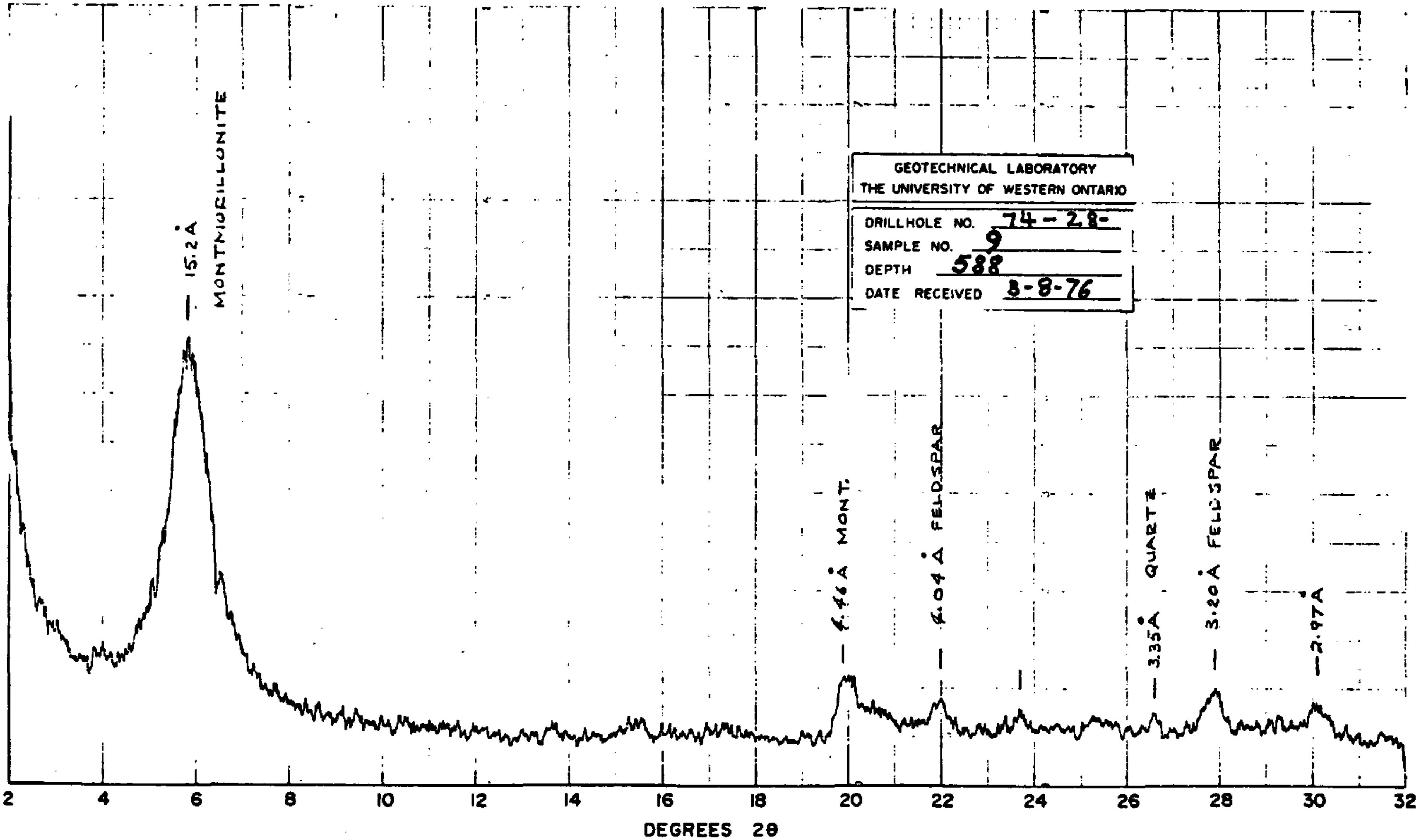

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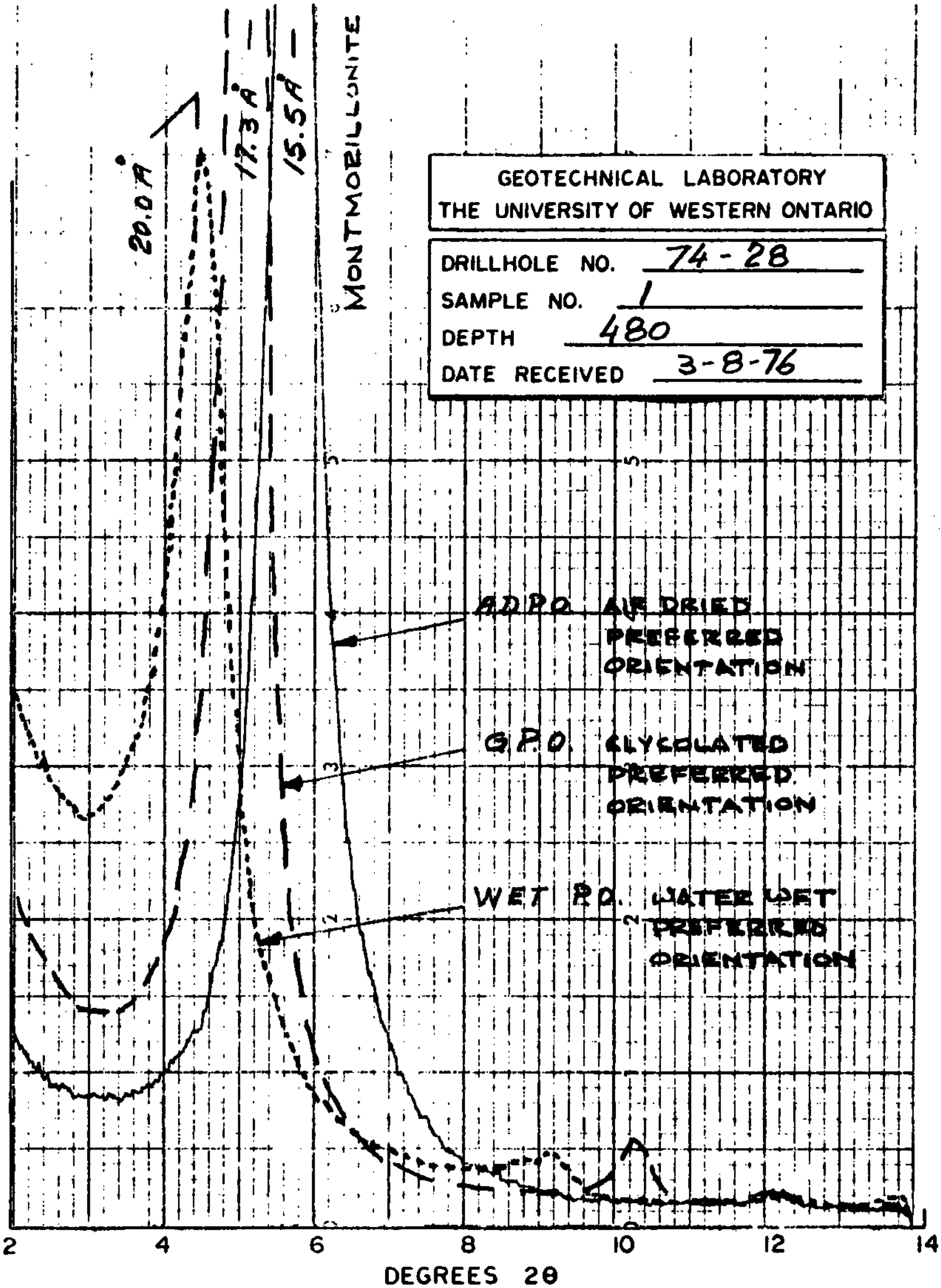
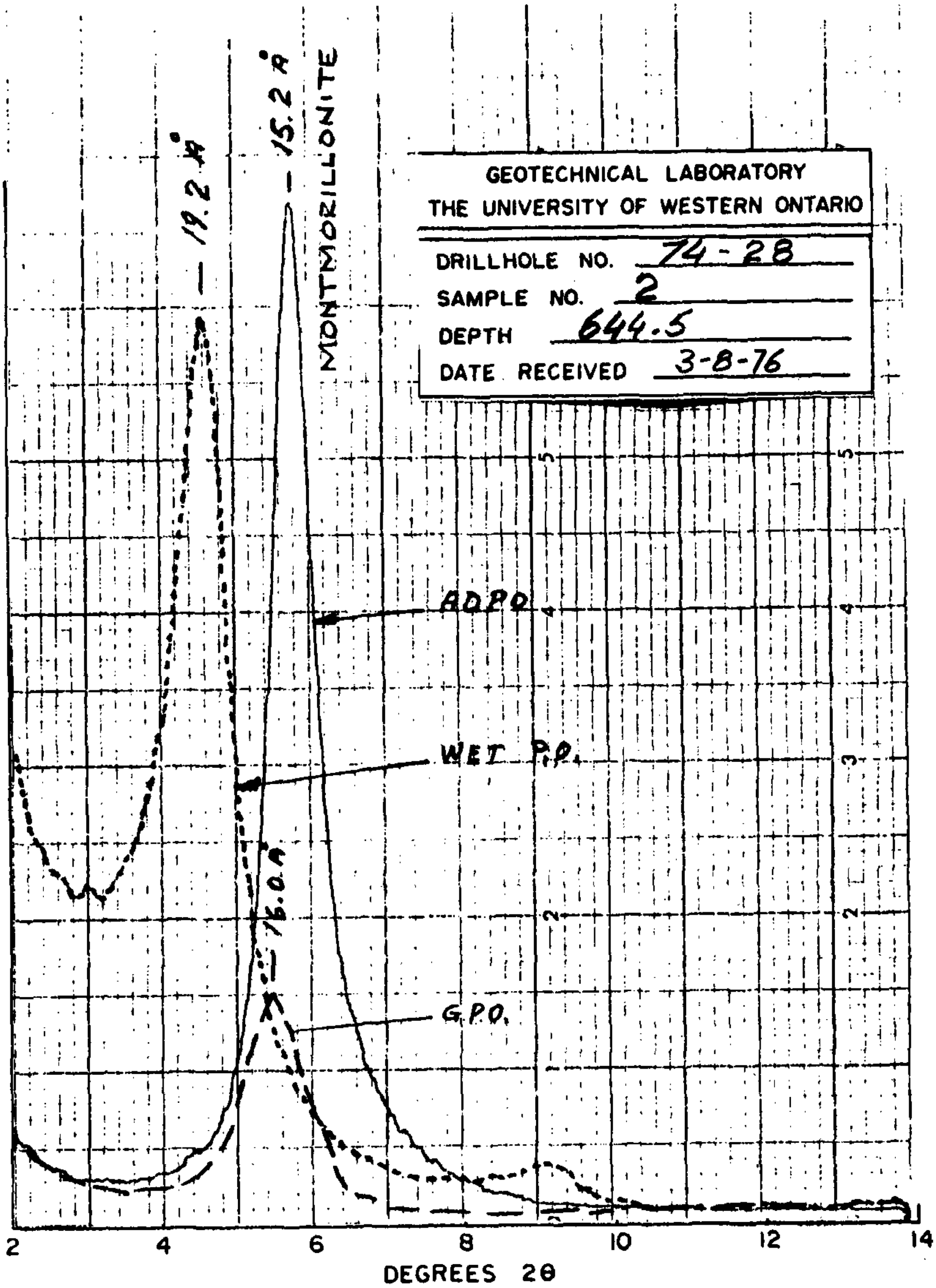


X-RAY DIFFRACTION TRACES OF 2μ, PREFERRED ORIENTED SPECIMENS FROM HAT CREEK.



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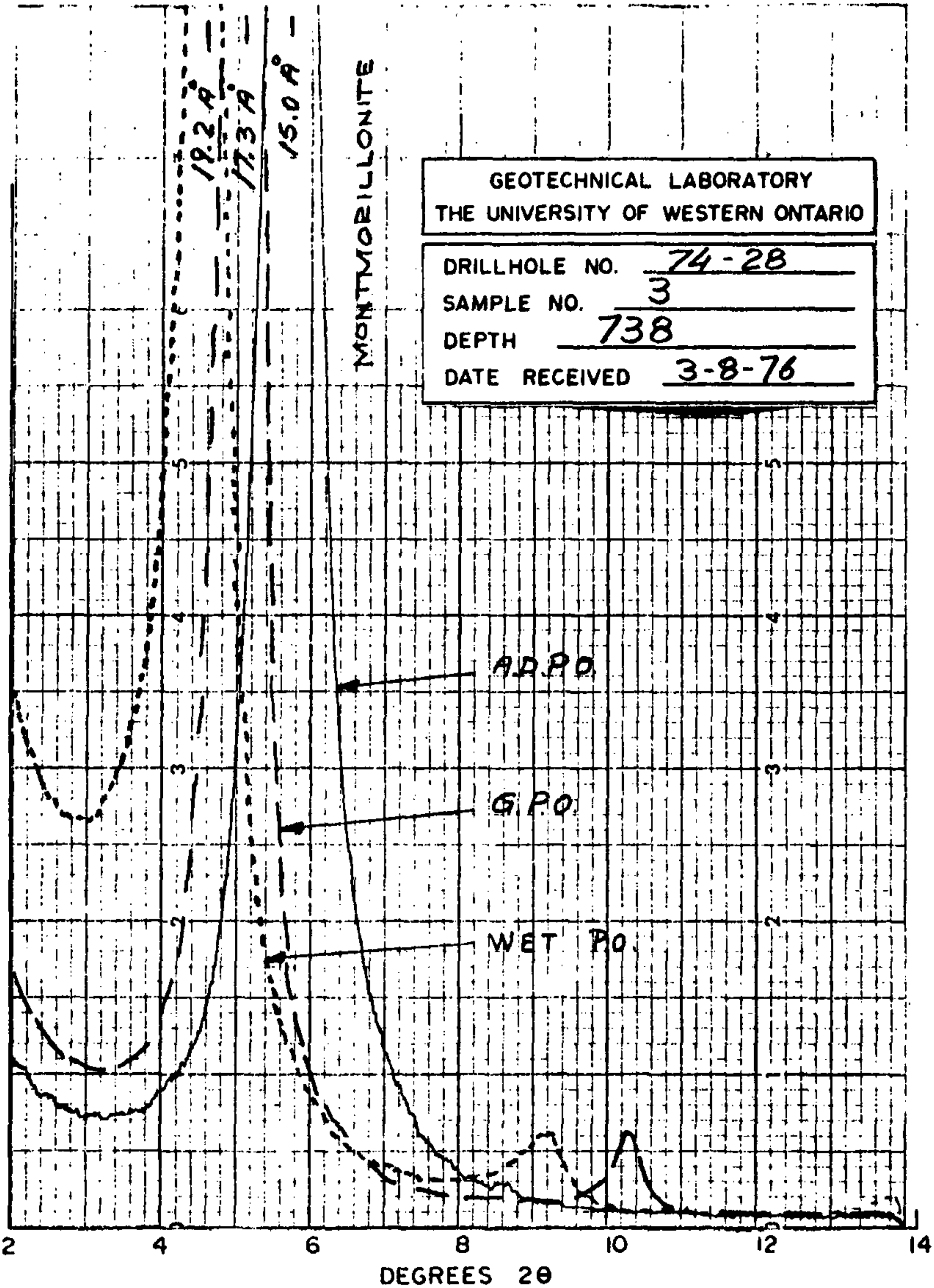

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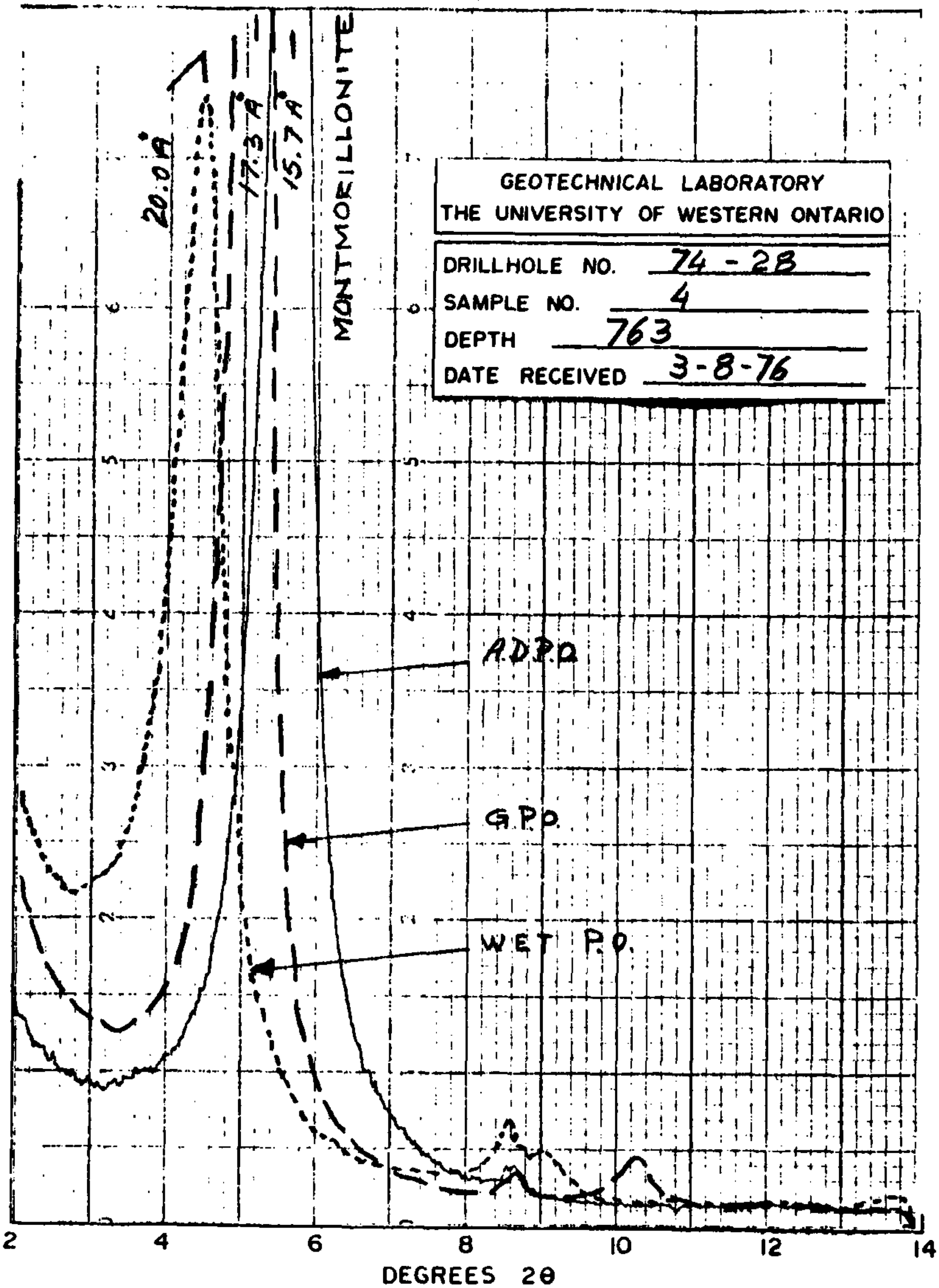

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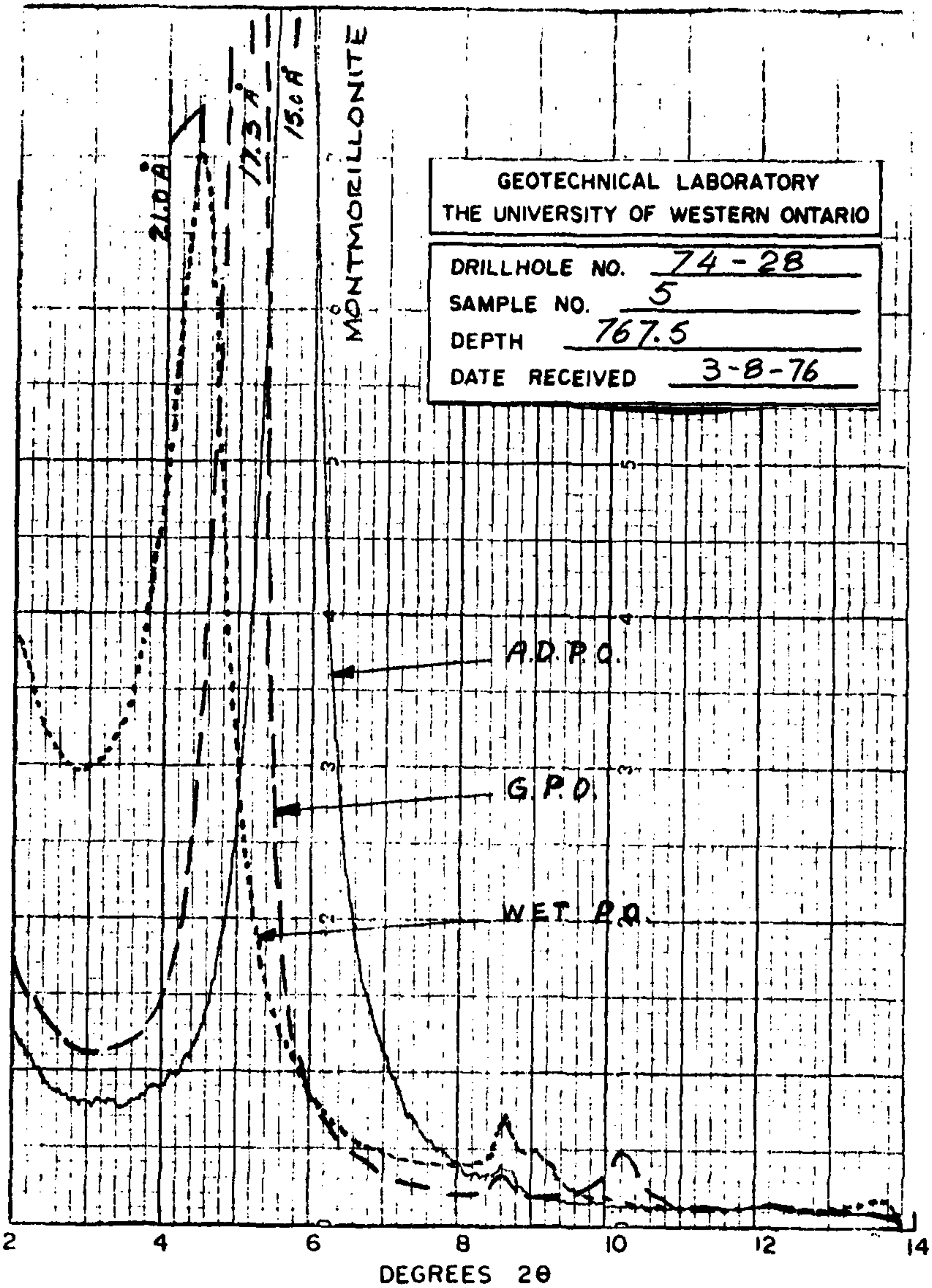

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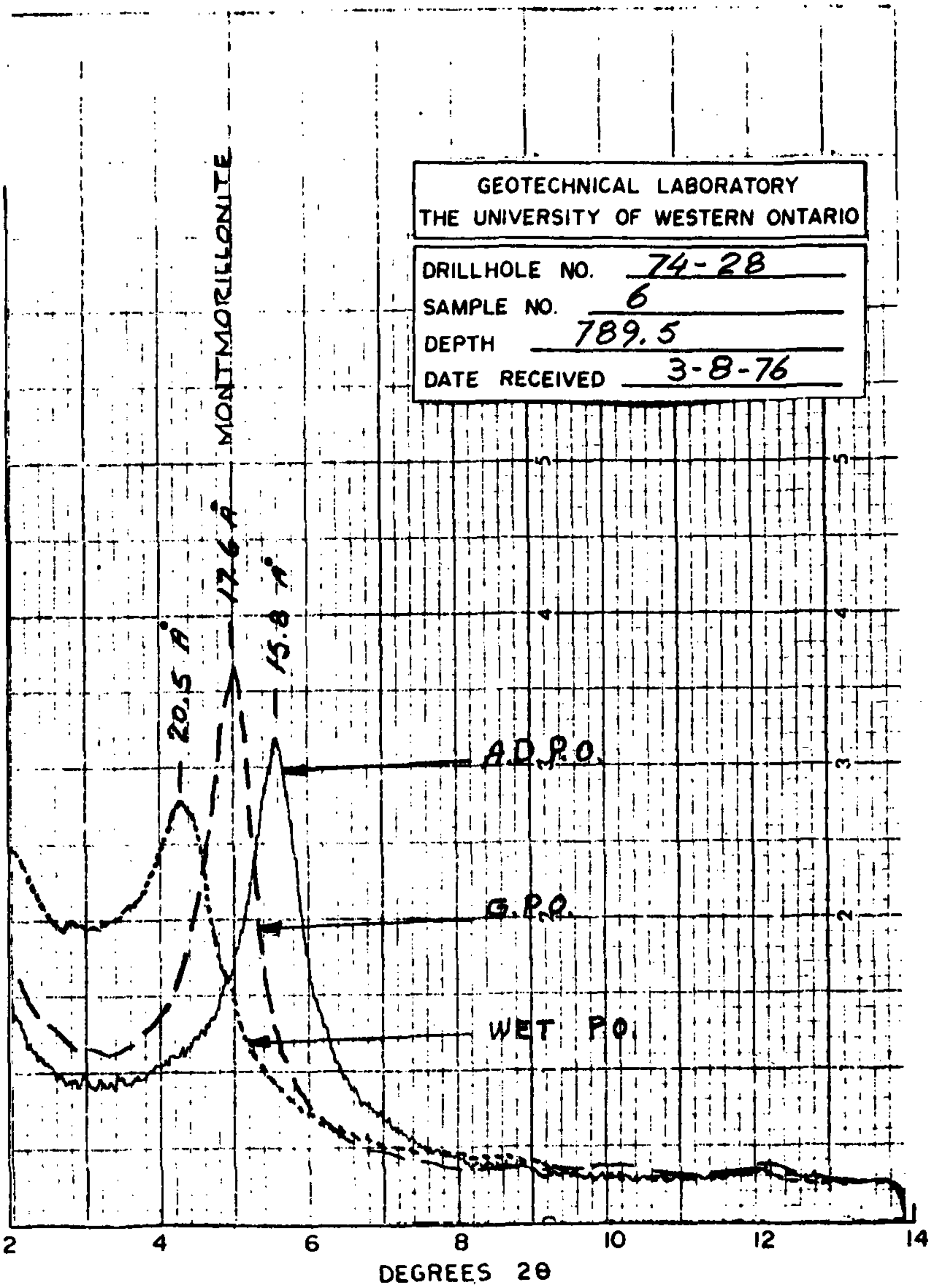

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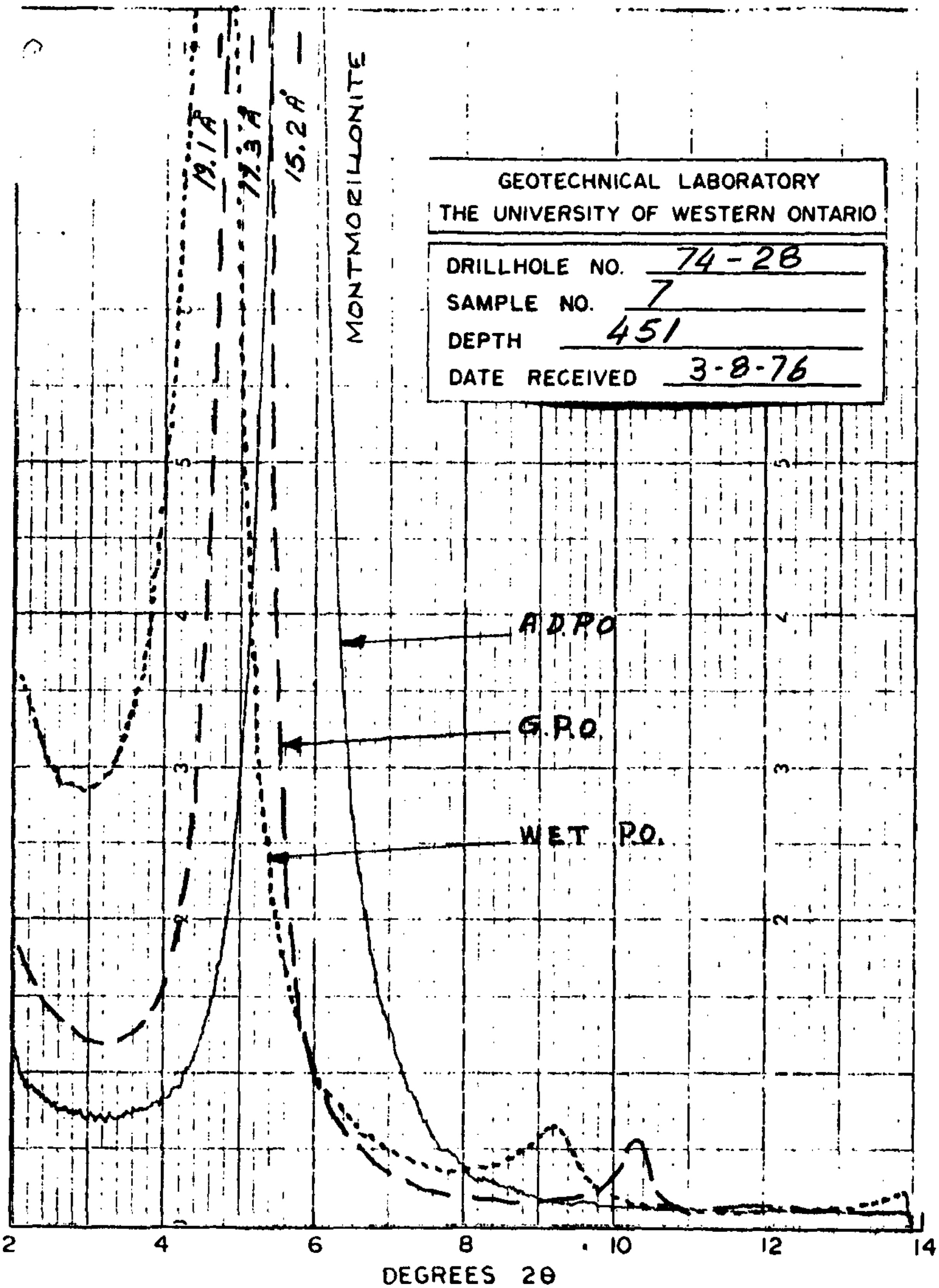

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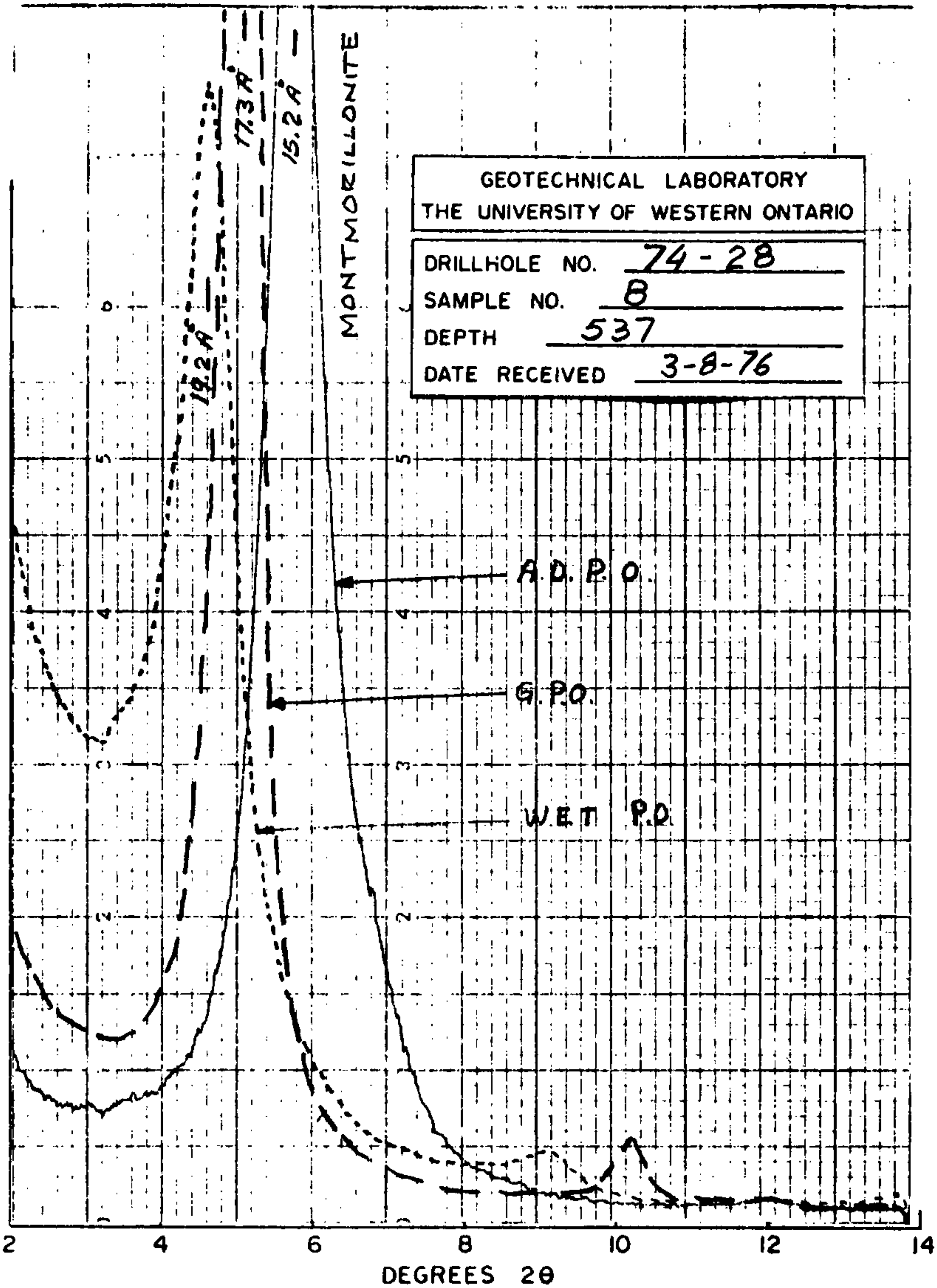

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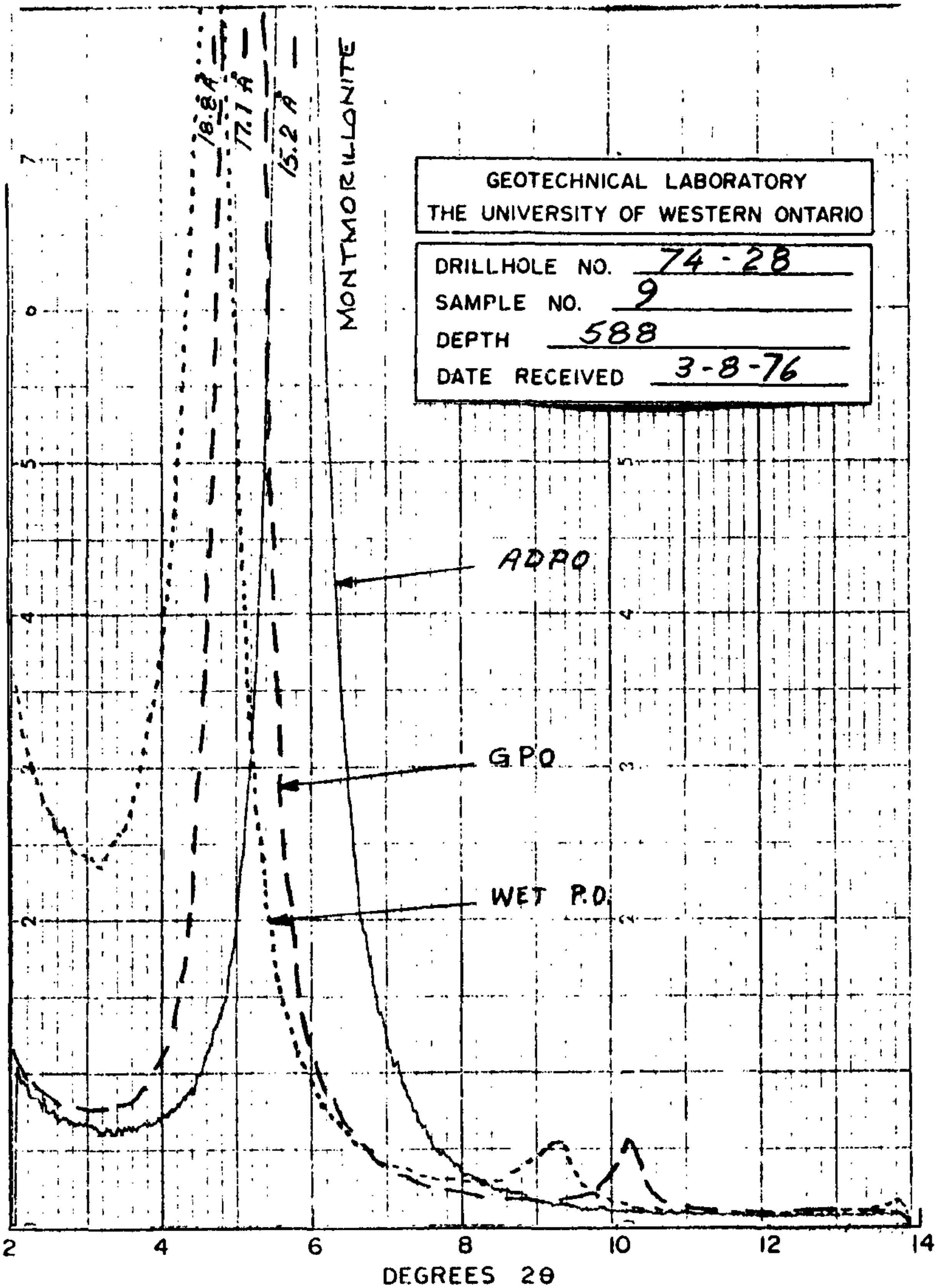


X-RAY DIFFRACTION TRACES OF 2 μ, PREFERRED ORIENTED SPECIMENS FROM HAT CREEK.

The University of Western Ontario

Faculty of Engineering Science
London, Canada
N6A 5B9

August 17, 1976

Mr. G. Rawlings
Golder, Brawner & Associates Ltd.
224 West 8th Avenue
Vancouver, B.C.
V5Y 1N5

Dear Mr. Rawlings:

Report #2 - Supplement
Hat Creek Project - Mineralogical Analyses
August 17, 1976

This supplement to Report #2 contains reruns of all powder x-rays on samples for B.H. #74-28. The traces were obtained on rocks more finely ground (<200 mesh) in an attempt to strengthen the x-ray peaks.

The traces are essentially as in the original report with strengthening of some of the peaks, especially those for siderite.

The most remarkable aspect of the powder patterns is the great size of the montmorillonite 15Å peak in all traces except B.H. #78-28 sample #6 where it is virtually absent. Montmorillonite is still present as shown in the preferred orientation traces for this sample in our Report #2.

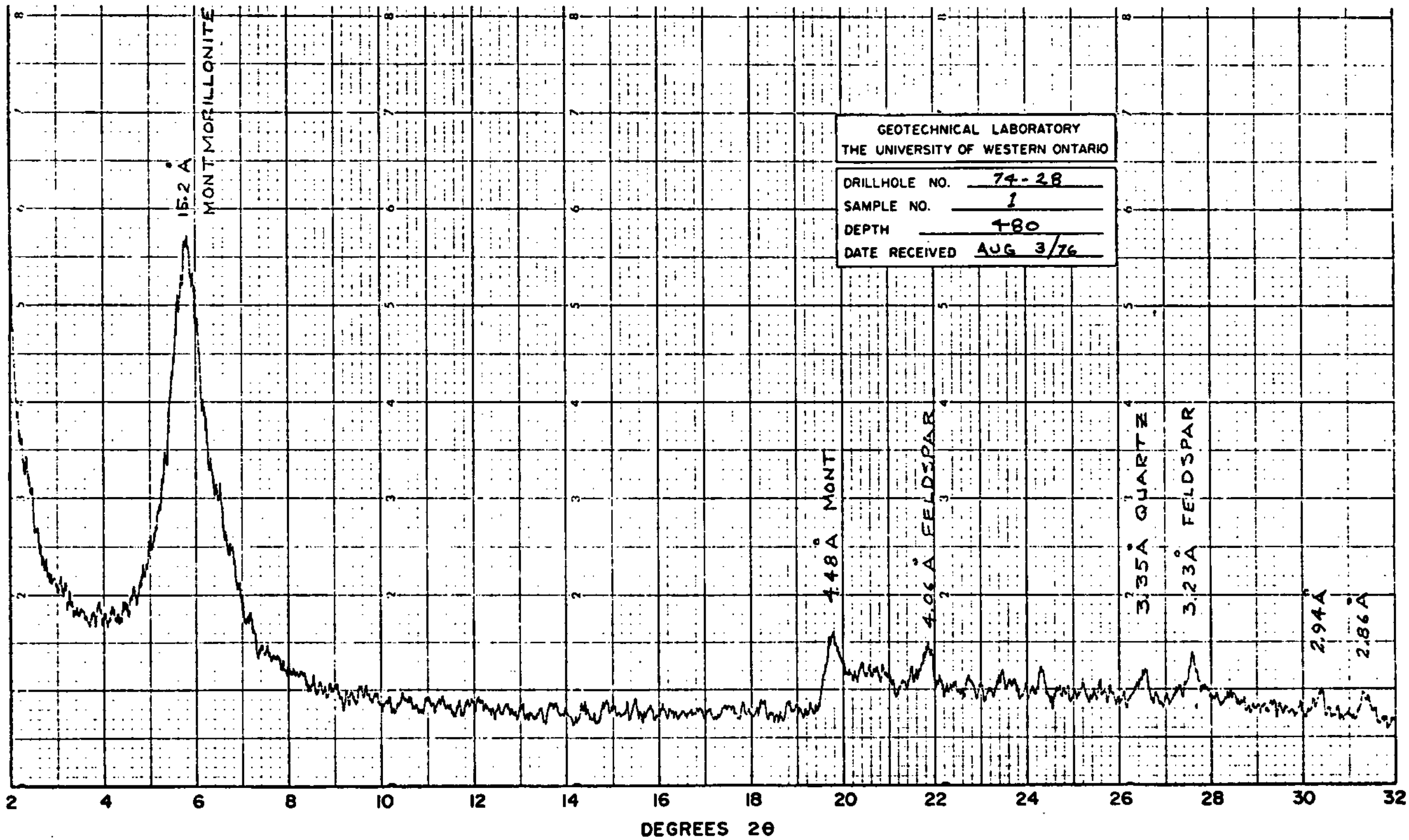
There is little evidence of cristobalite and other ash derived minerals in the rocks analyzed to date except possibly sample 74-28-2 in which a 4.06Å peak without other feldspar peaks could possibly be cristobalite.

Yours sincerely,

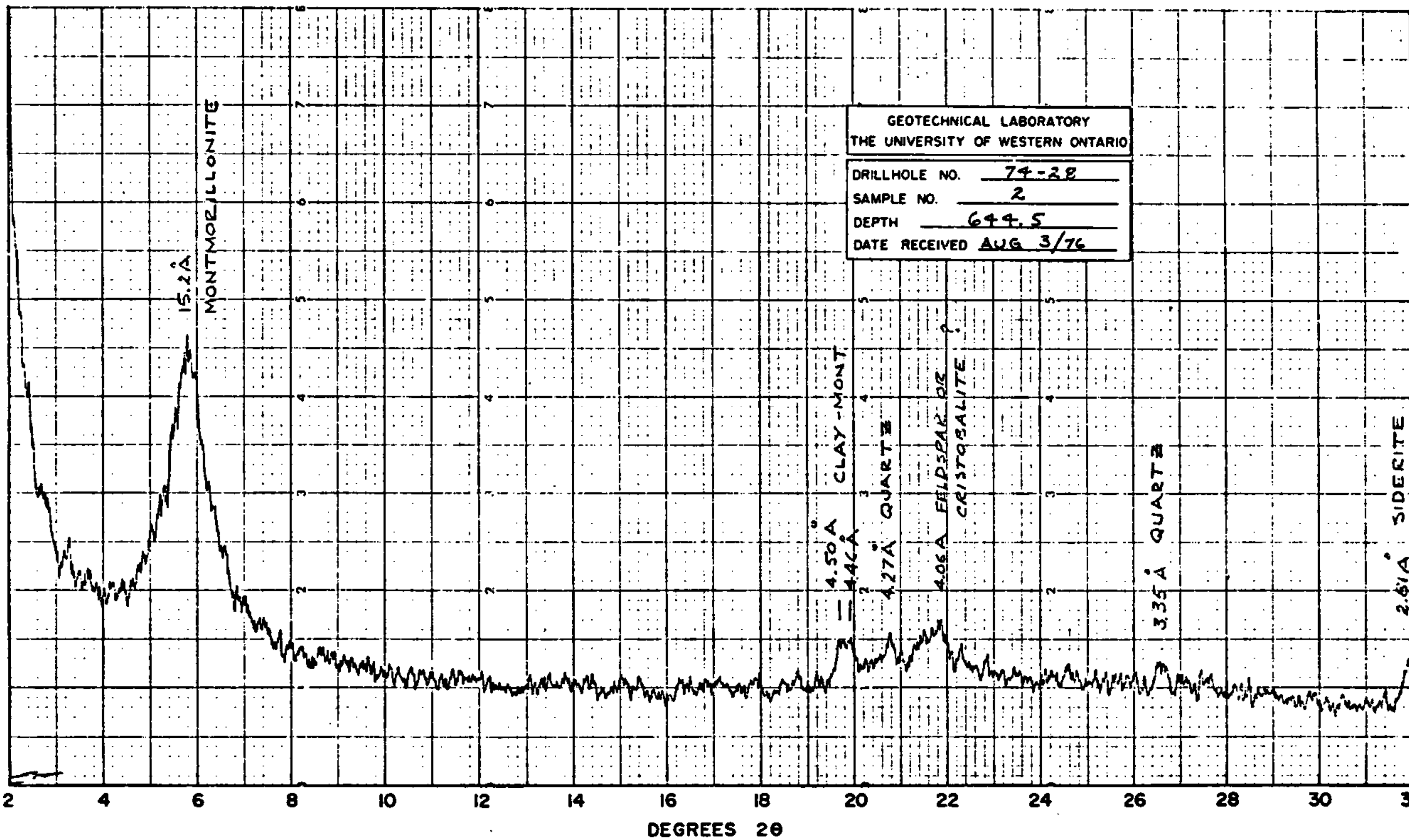
R.M. Quigley

R.M. Quigley, P.Eng.
Professor of Geotechnical Engineering

RMQ/jl
Attach.
cc. Mr. H. Hawson



X-RAY DIFFRACTION TRACES OF WHOLE SOIL POWDERS FROM HAT CREEK.



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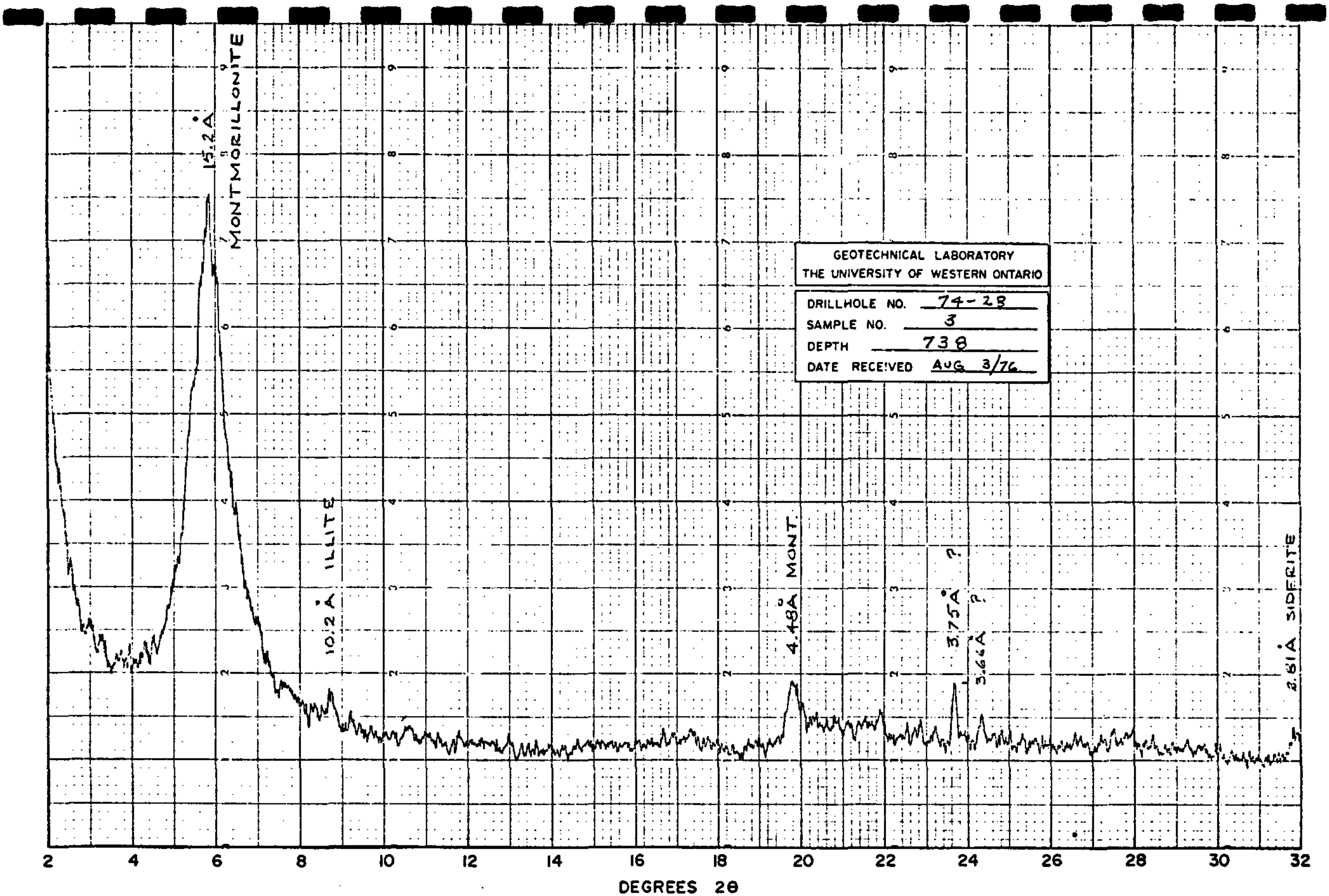

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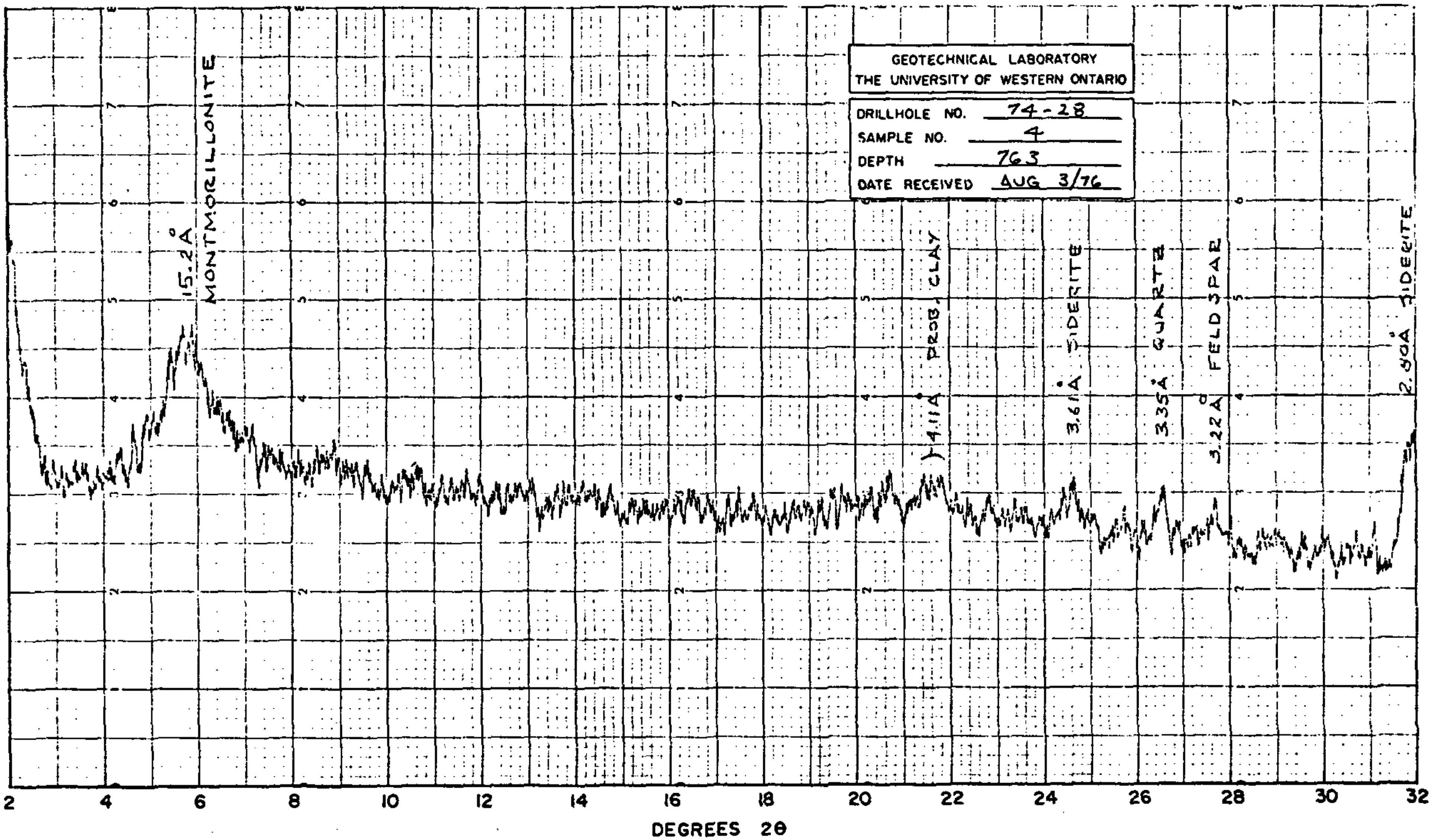

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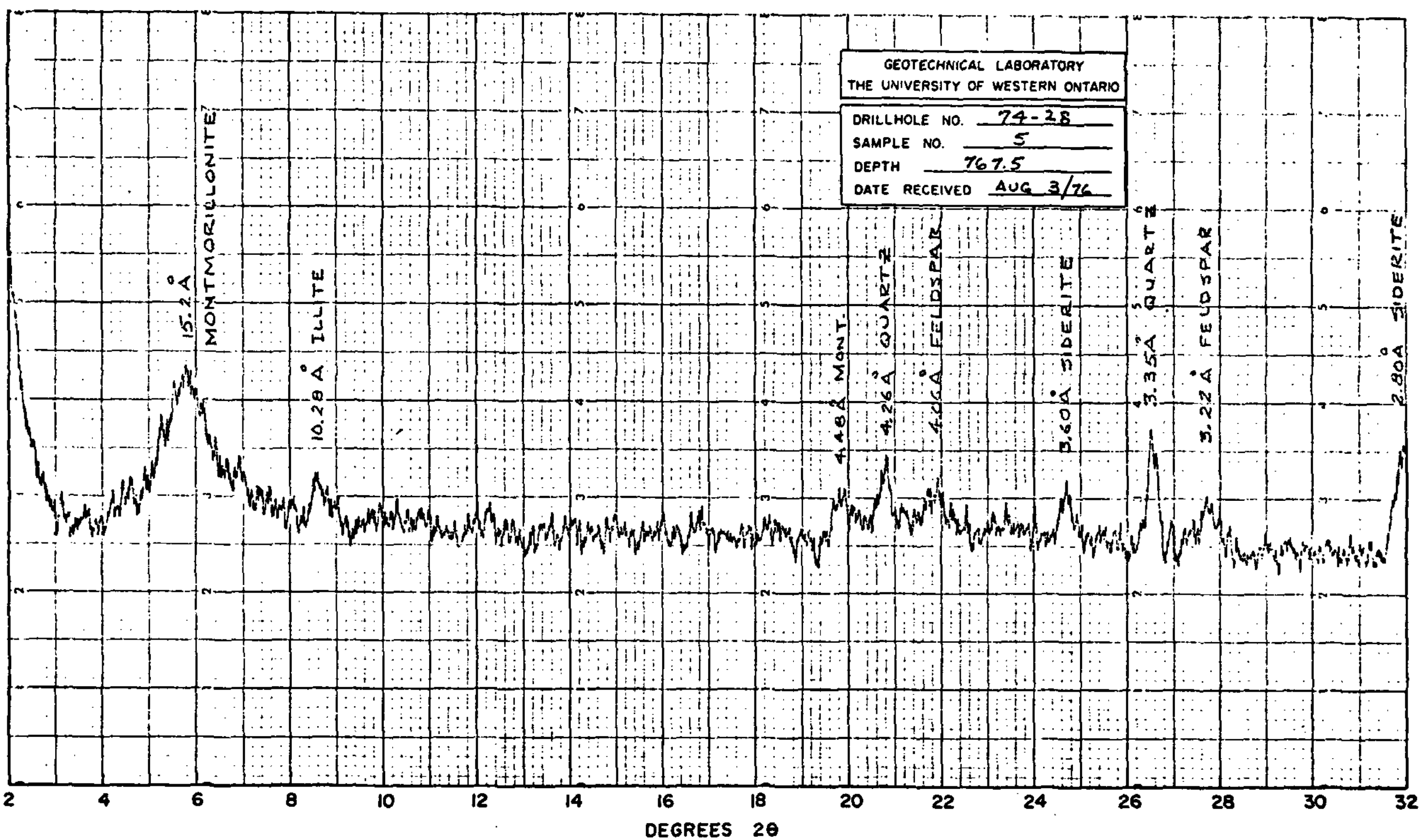

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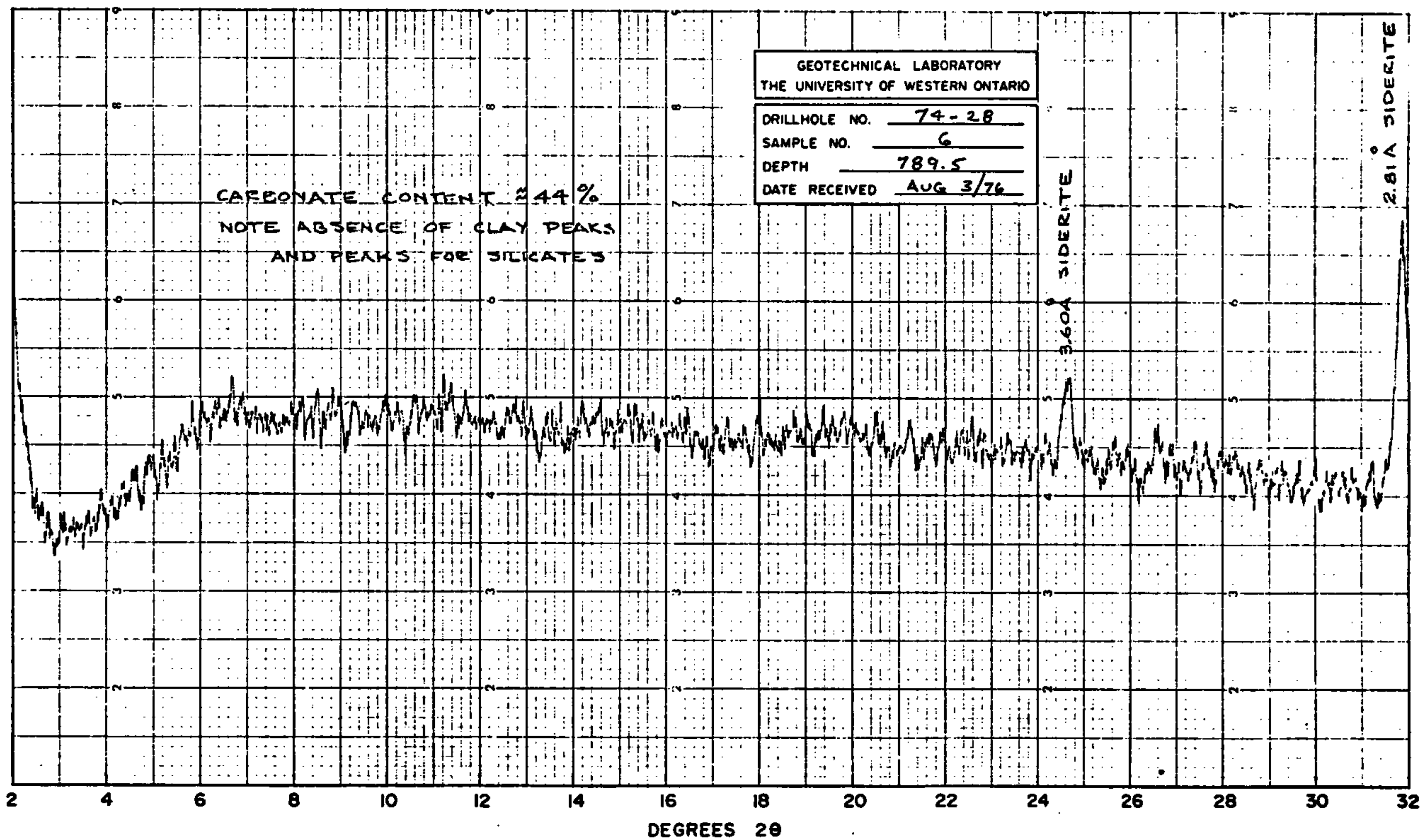

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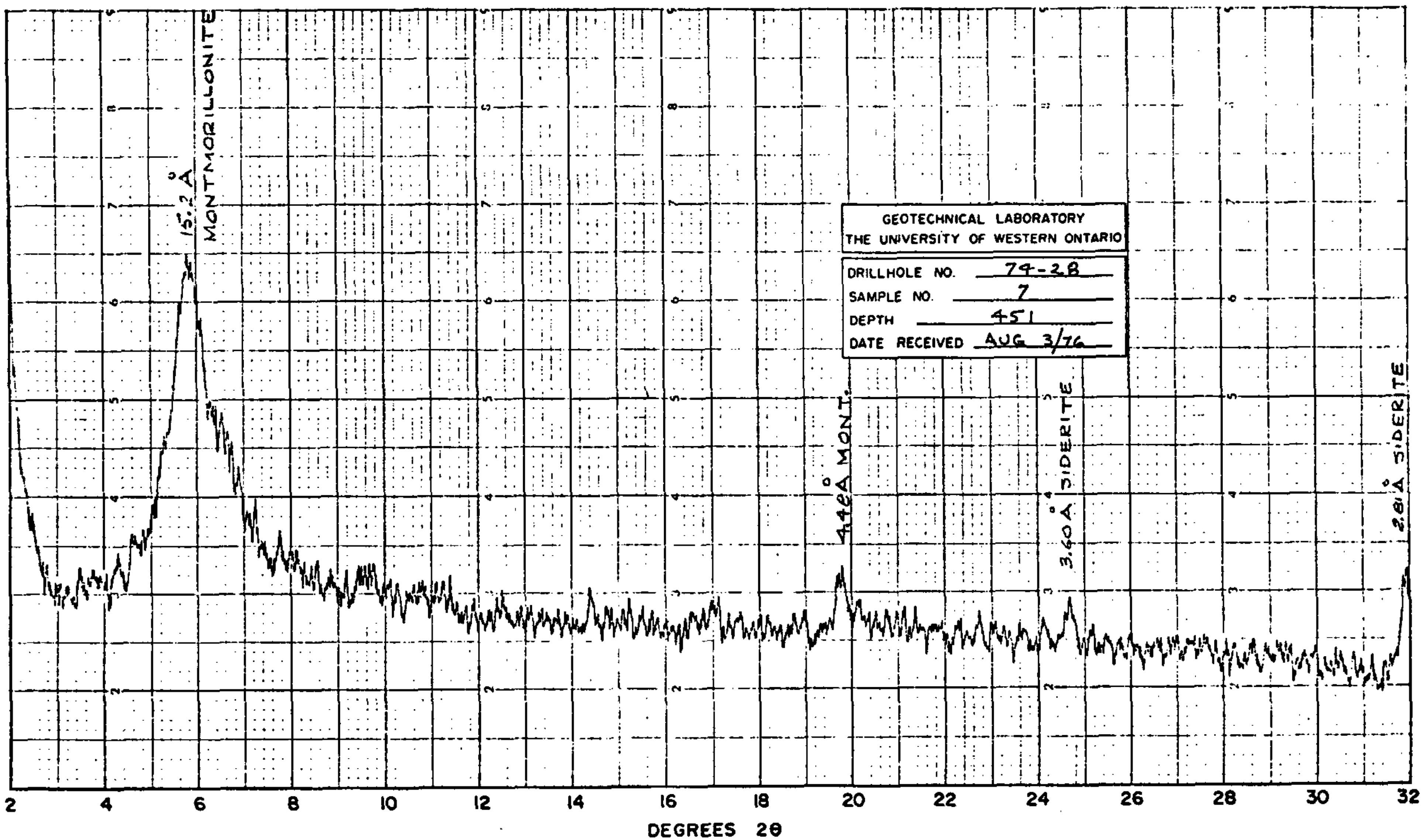

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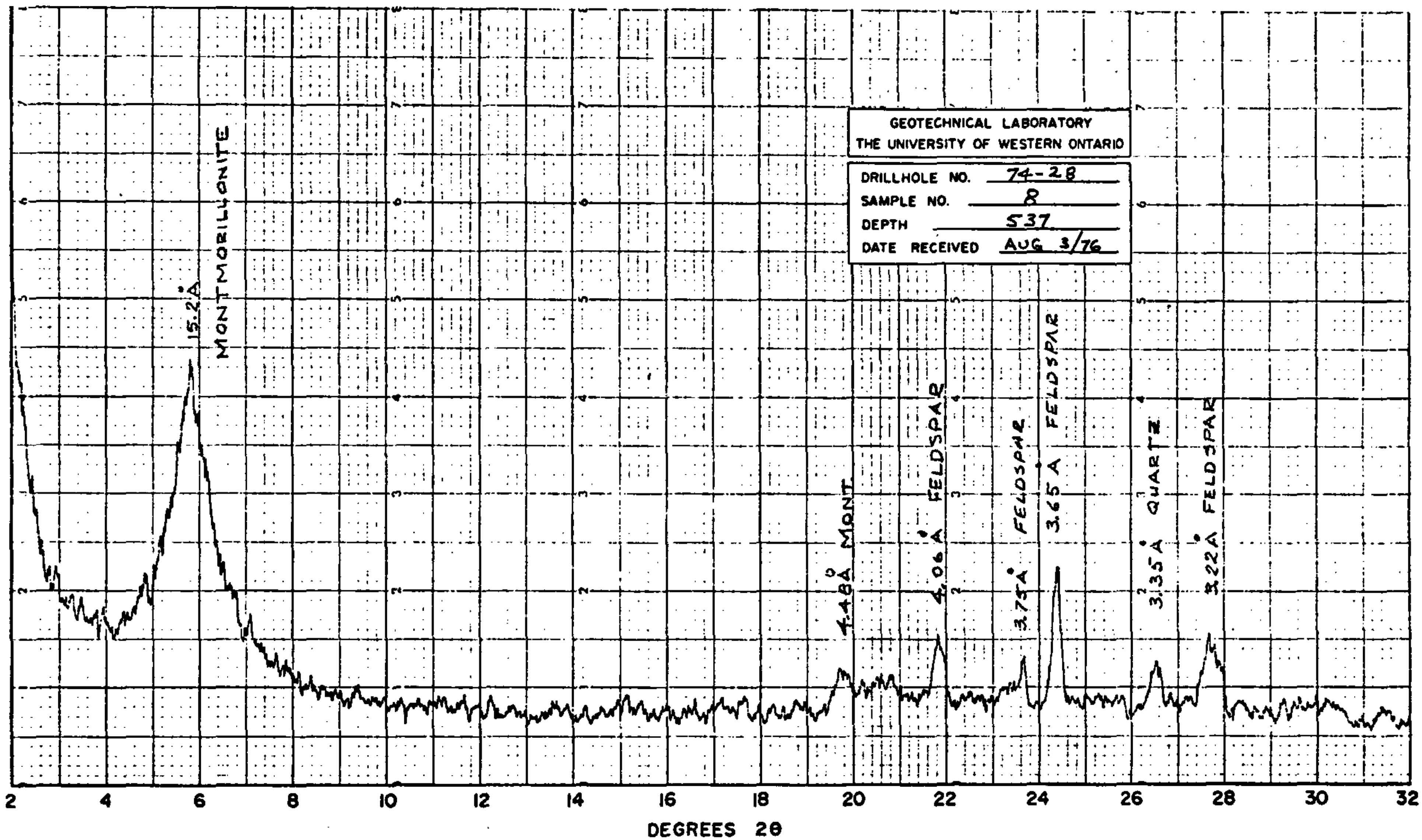

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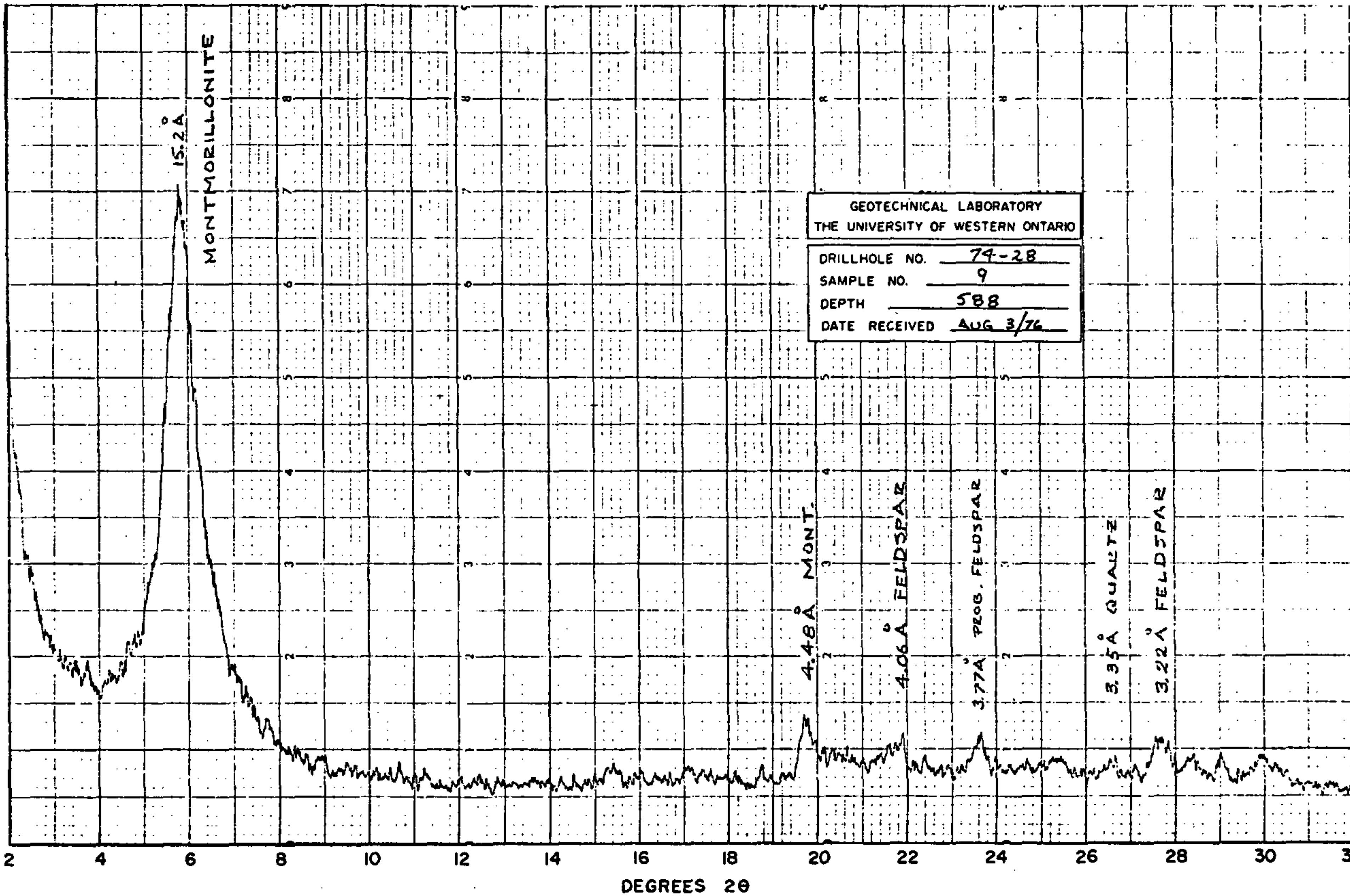


X-RAY DIFFRACTION TRACES OF WHOLE SOIL POWDERS FROM HAT CREEK.

FEB 15 1977

FILE No.

The University of Western Ontario, London, Canada

Faculty of Engineering Science
London, Canada
N6A 5B9

20 August 1976

Mr. G. Rawlings
Golder, Brawner & Associates Ltd.
224 West 8th Avenue
Vancouver, British Columbia
V5Y 1N5

Dear Mr. Rawlings:

Report #3 - Hat Creek Project - Mineralogical Analyses
August 20, 1976

We have completed x-ray and carbonate analyses on eight samples from borehole 76-815 received from Mr. H. Hawson on August 3, 1976. We have yet to complete the x-ray and carbonate analyses on eight further samples, however, these will be forwarded to you in early September.

During September we will also run the selected Na^+ analyses and glycol retention values on the samples received to date.

Comments on Borehole 76-815

1. Carbonate analyses supplemented by the x-ray powder patterns showed the heavily indurated rocks to consist of 34 to 68% siderite. All rocks supplied from this hole reacted with HCl (when powdered) indicating some carbonate.

2. Where siderite was very abundant (Sa. #7, 9, 18, 22 and 29) the montmorillonite peaks were very weak or absent on the powder patterns. An absence of other peaks indicates a scarcity of silicate minerals noticed in previous rock samples.

3. Montmorillonite was confirmed to be present in the < 2 μm fraction of all rocks as shown by the x-ray traces on oriented specimens.

4. It is concluded that the rock specimens supplied from this borehole consist dominantly of montmorillonite and siderite. Quartz and feldspar are rare (< 10%) and clearly observed only on two powder patterns for samples #12 and 20.

Yours sincerely,

R.M. Quigley

R.M. Quigley, P.Eng.
Professor of Geotechnical Engineering

RMQ:em

c.c. H. Hawson ✓

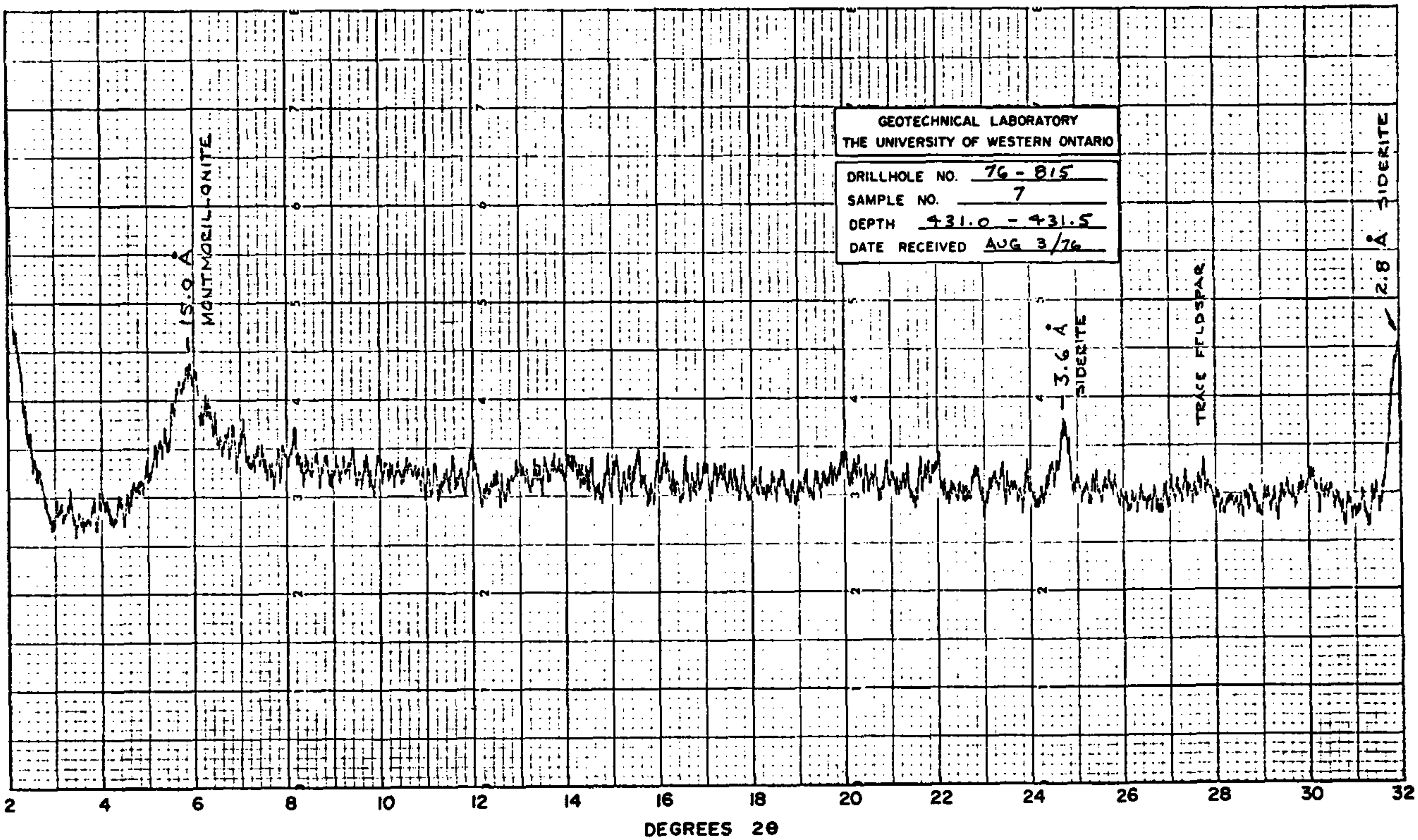
HAT CREEK PROJECT LIST OF SAMPLES RECEIVED FROM GOLDER BRAWNER & ASSOCIATES	GEOTECHNICAL LABORATORY THE UNIVERSITY OF WESTERN ONTARIO

Drill Hole No.	Sample No.	Depth (Feet)	Date Received	Testing Completed						
				X-ray				Carbonate (%)	Glycol Retention (mg/g)	Na^+ (PPM)
				Wet P.O.	ADPO	GPO	Powder			
76-815	7	431.0-431.5	AUG 3/76	✓	✓	✓	✓	34.5		
76-815	9	447.8-448.1	AUG 3/76	✓	✓	✓	✓	51.2		
76-815	12	482.3-482.6	AUG 3/76	✓	✓	✓	✓	3.5		
76-815	14	505.6-506.0	AUG 3/76	✓	✓	✓	✓	7.5		
76-815	18	541.5-542.0	AUG 3/76	✓	✓	✓	✓	34.3		
76-815	20	561.7-562.3	AUG 3/76	✓	✓	✓	✓	9.3		
76-815	22	582.7-583.2	AUG 3/76	✓	✓	✓	✓	67.6		
76-815	29	669.0-669.7	AUG 3/76	✓	✓	✓	✓	35.5		

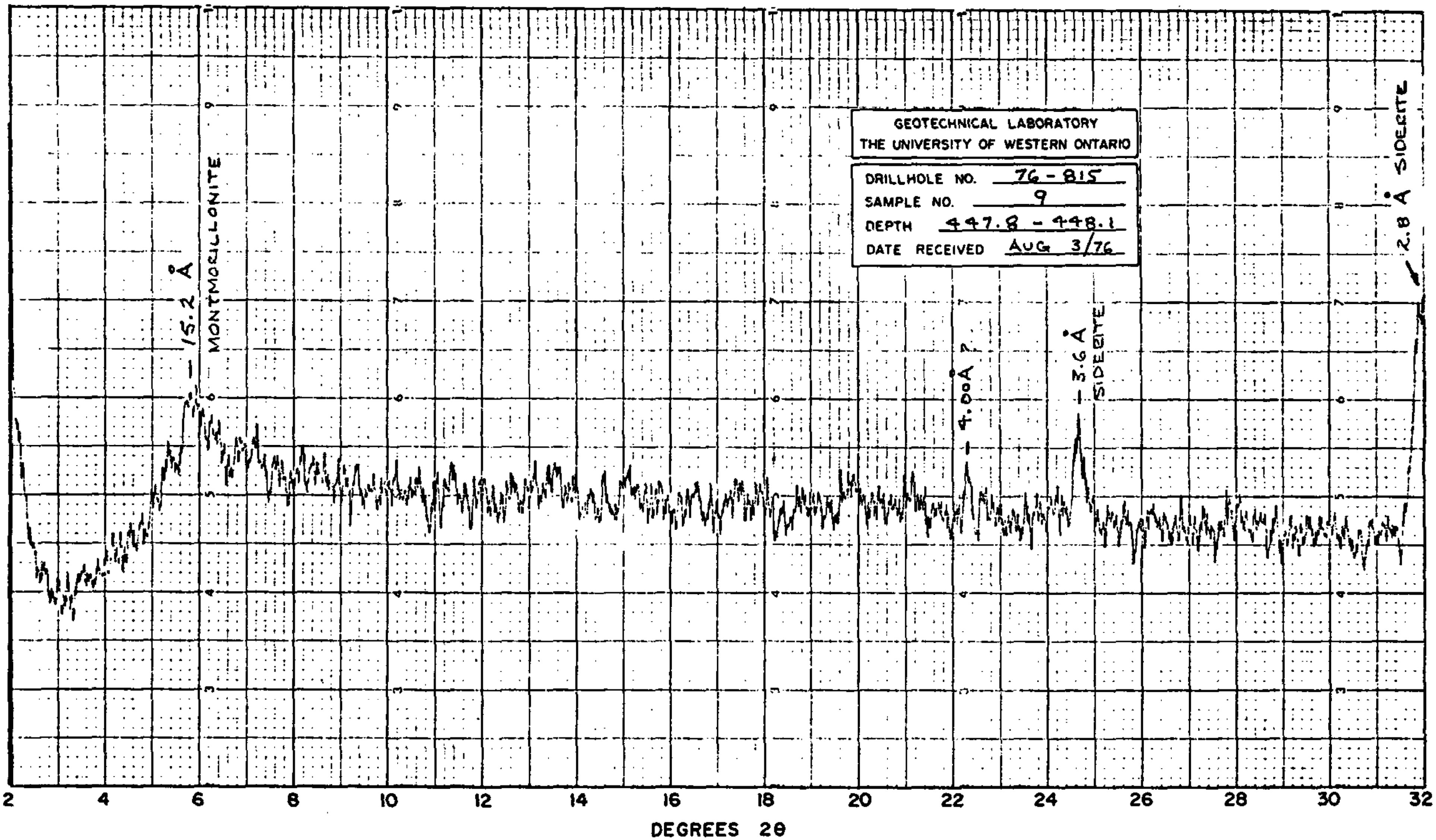
REPORT #3

R.M. Quigley

Aug. 20, 1976



X-RAY DIFFRACTION TRACES OF WHOLE SOIL POWDERS FROM HAT CREEK.



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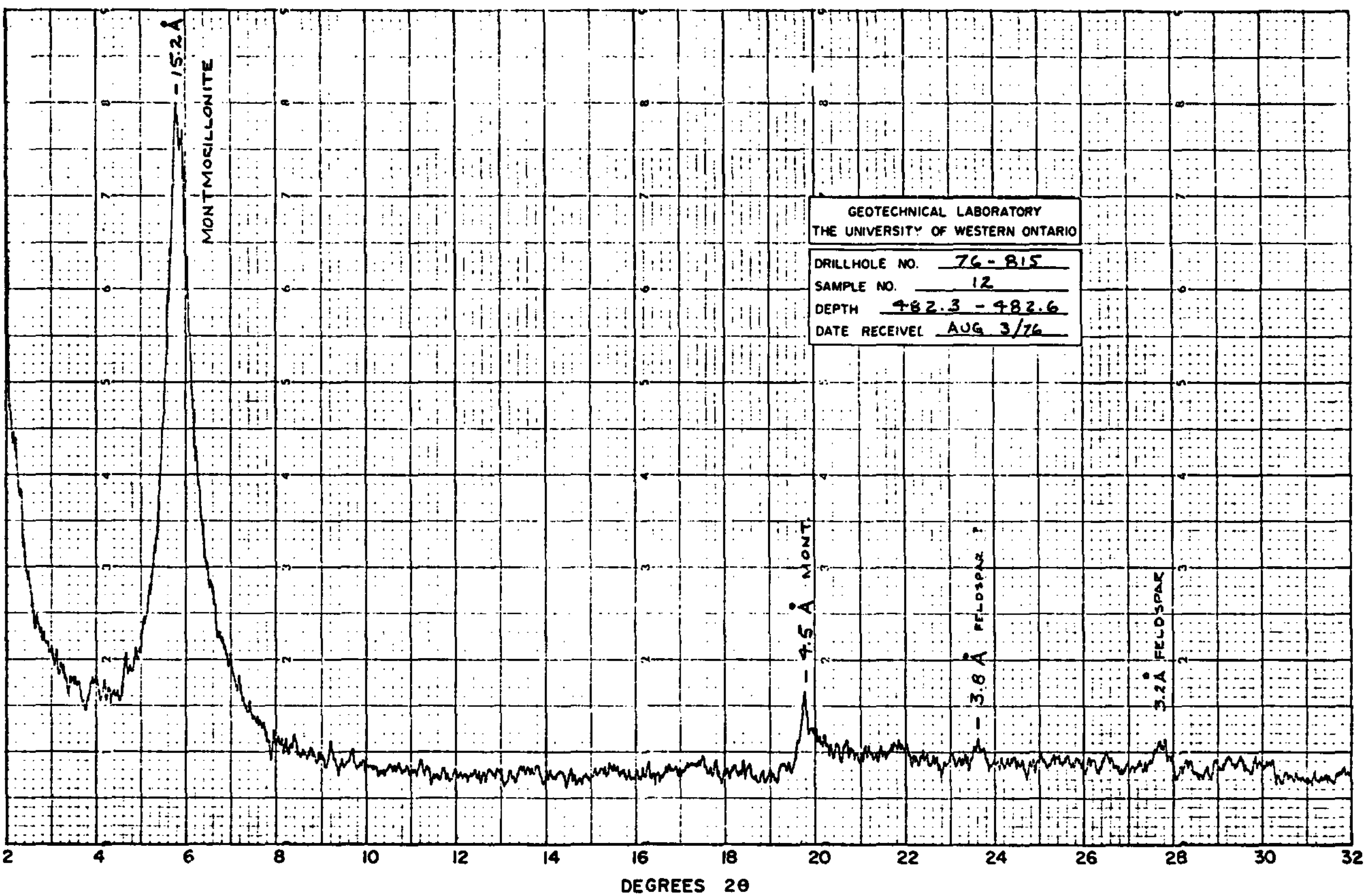

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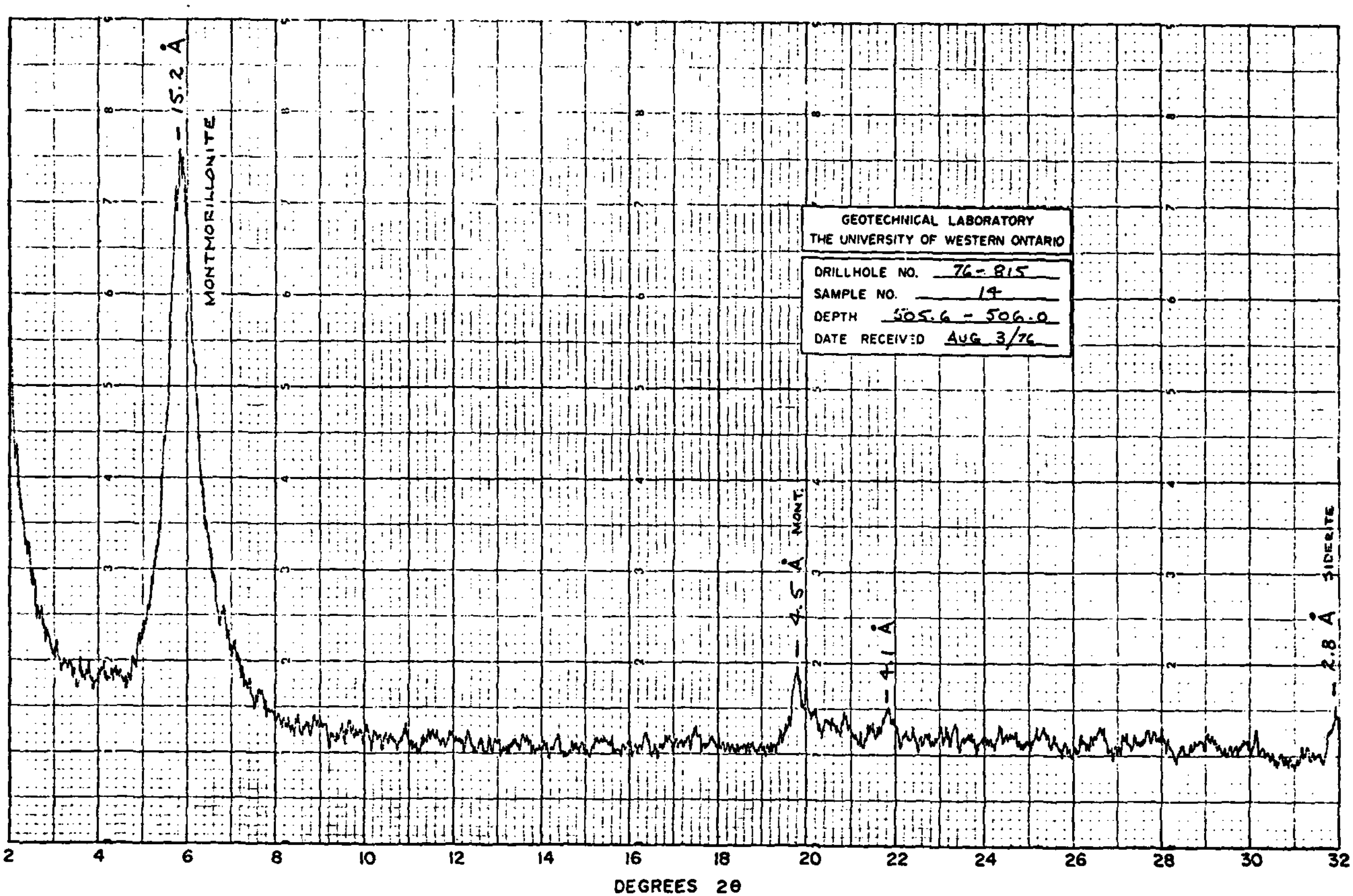

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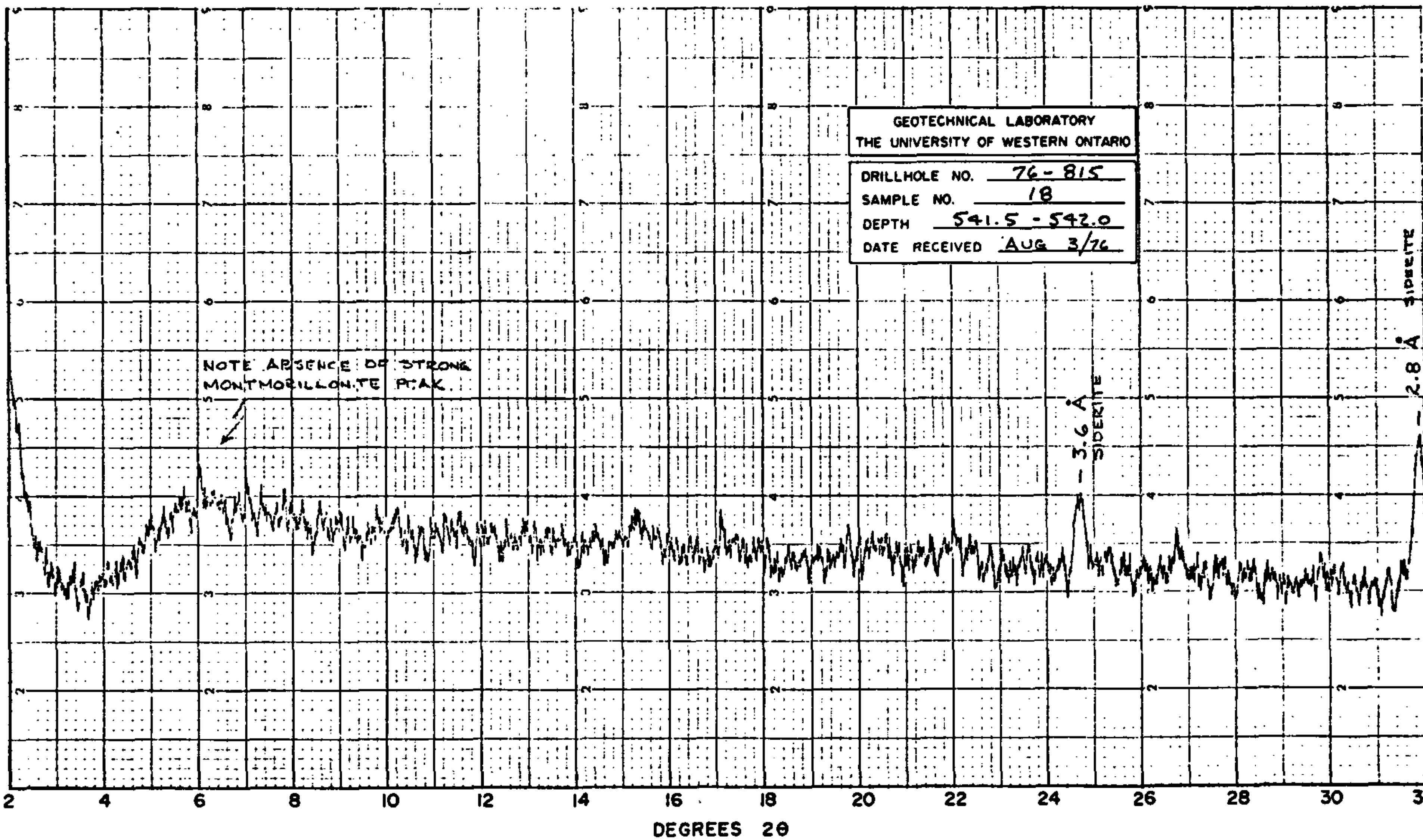

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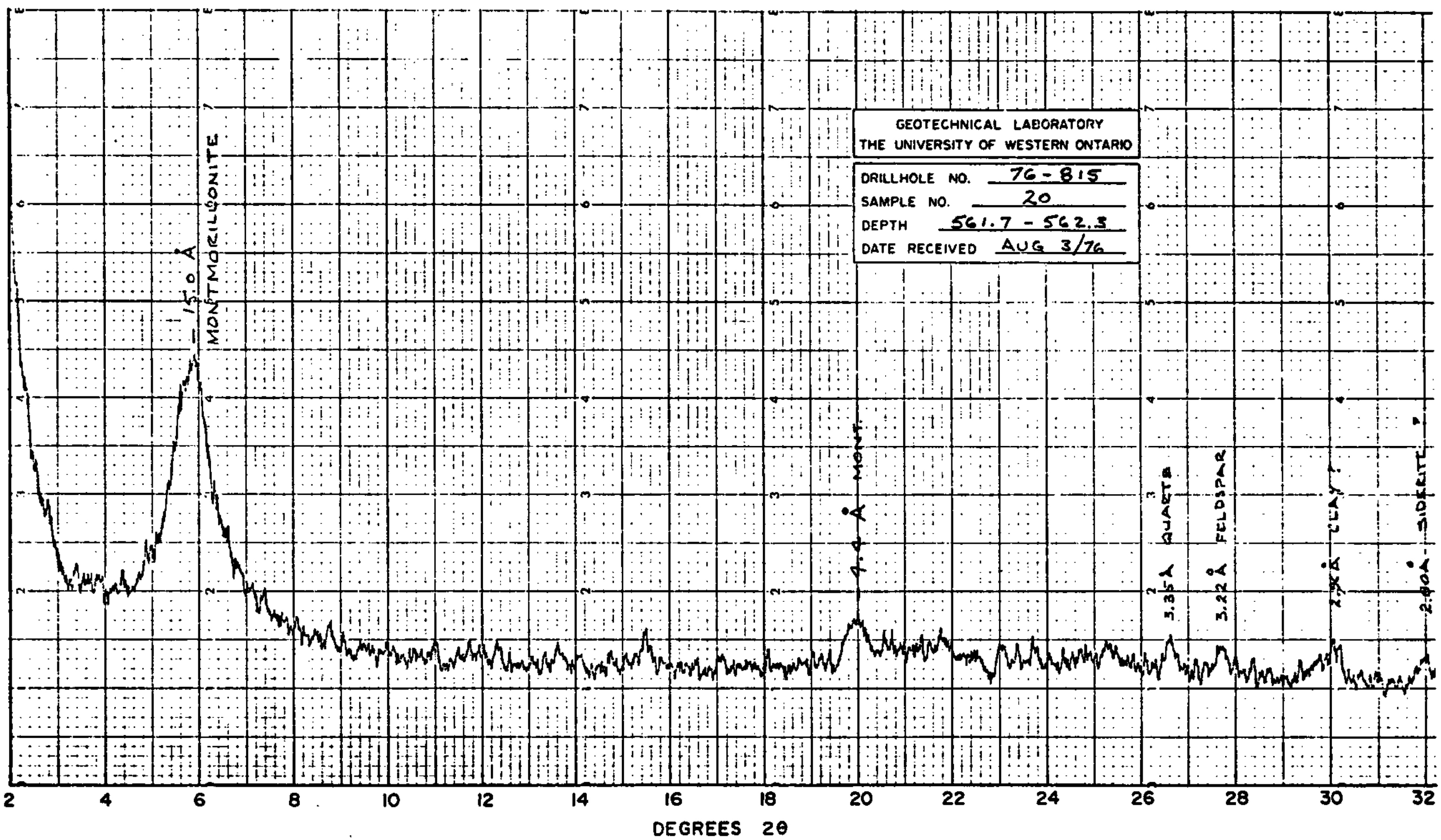

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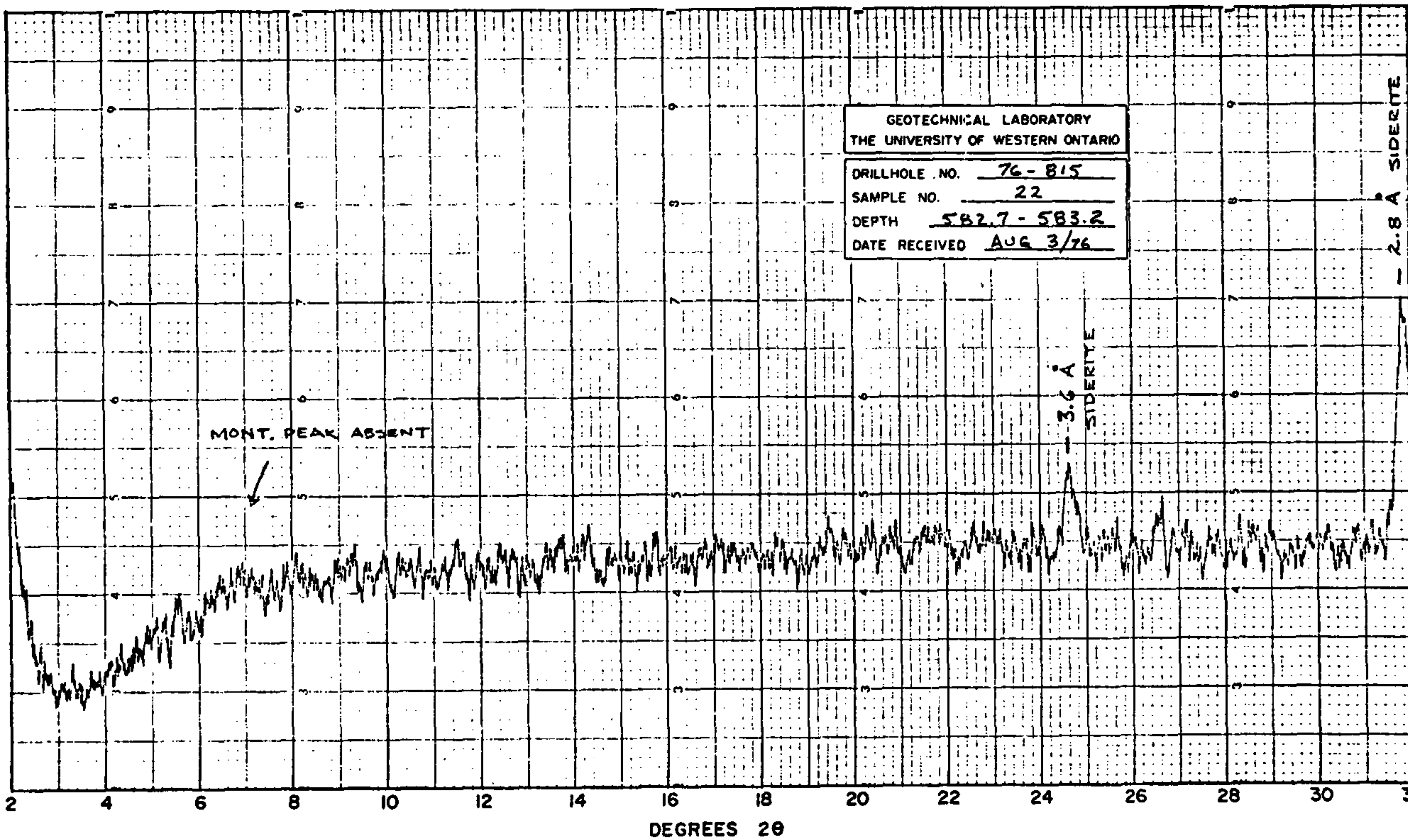

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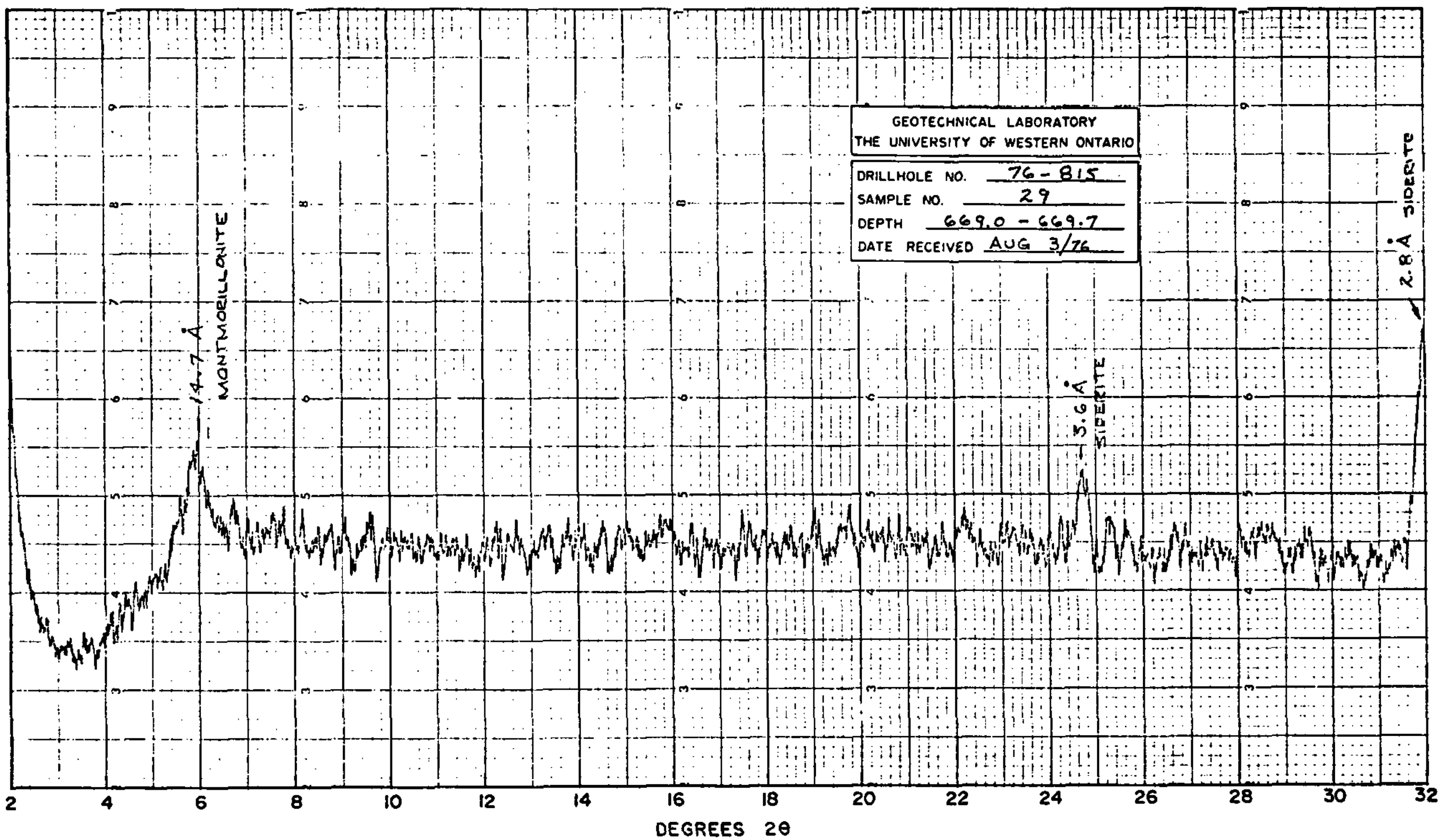

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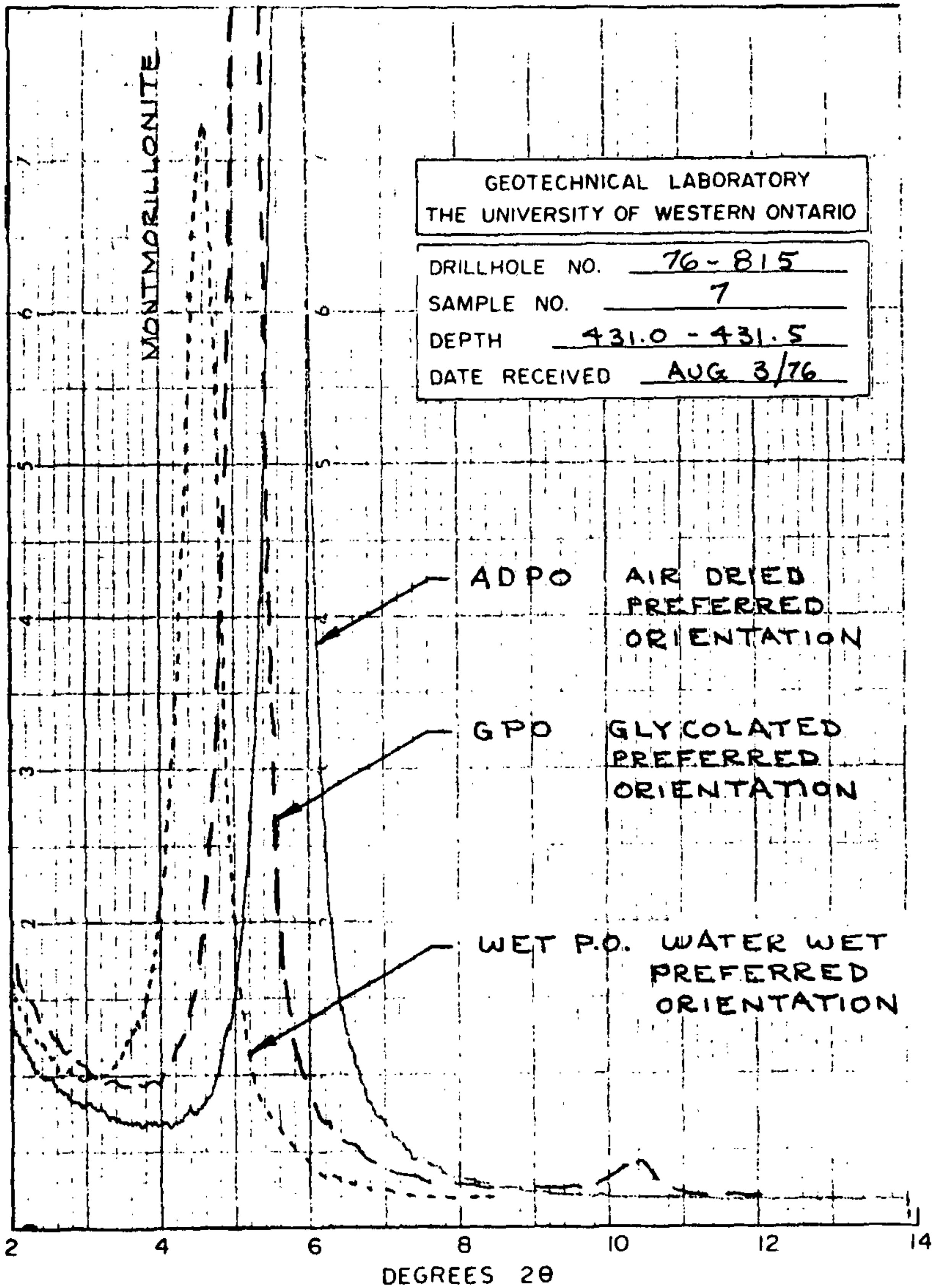
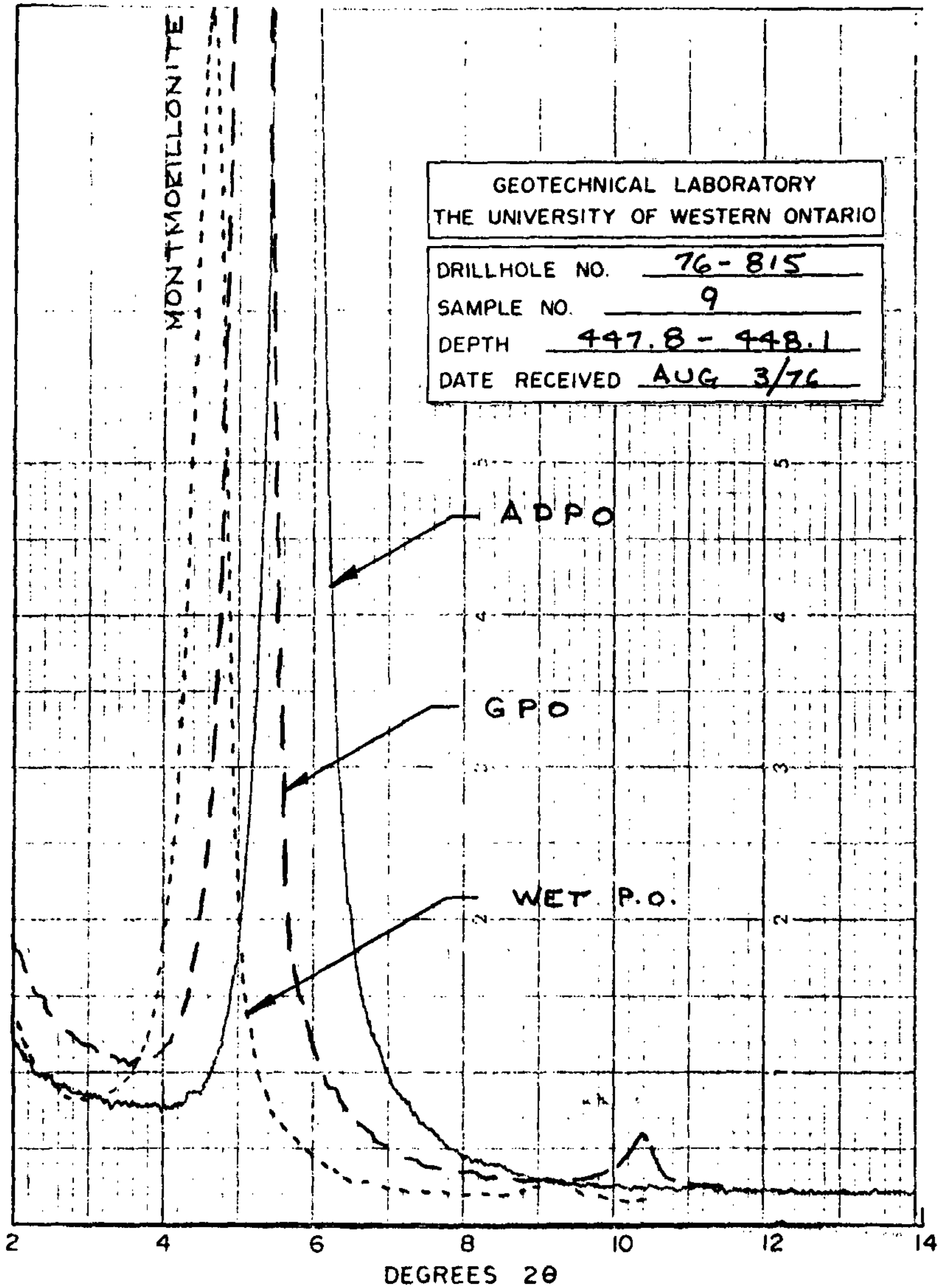


X-RAY DIFFRACTION TRACES OF 2 μ, PREFERRED ORIENTED SPECIMENS FROM HAT CREEK.



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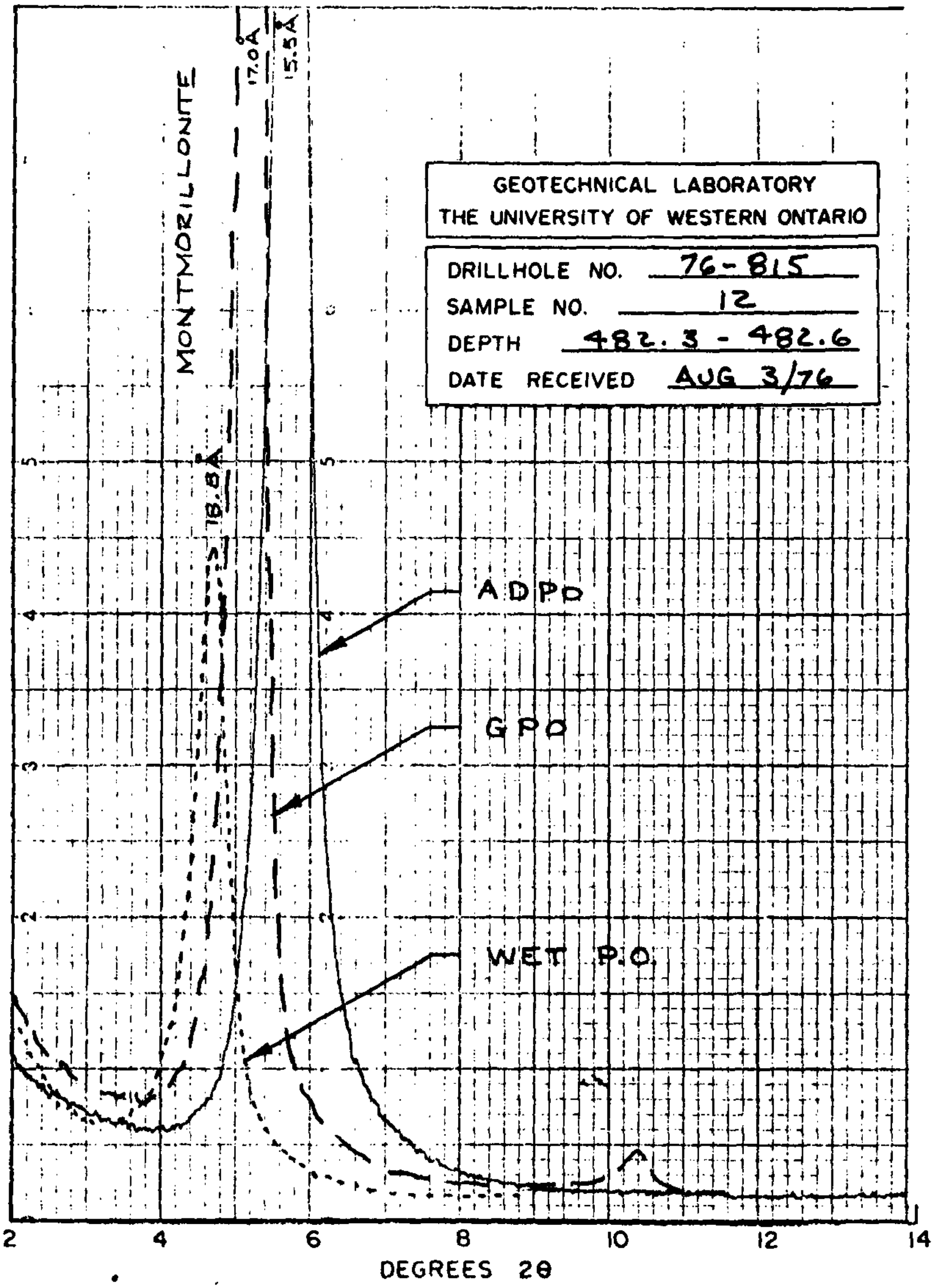

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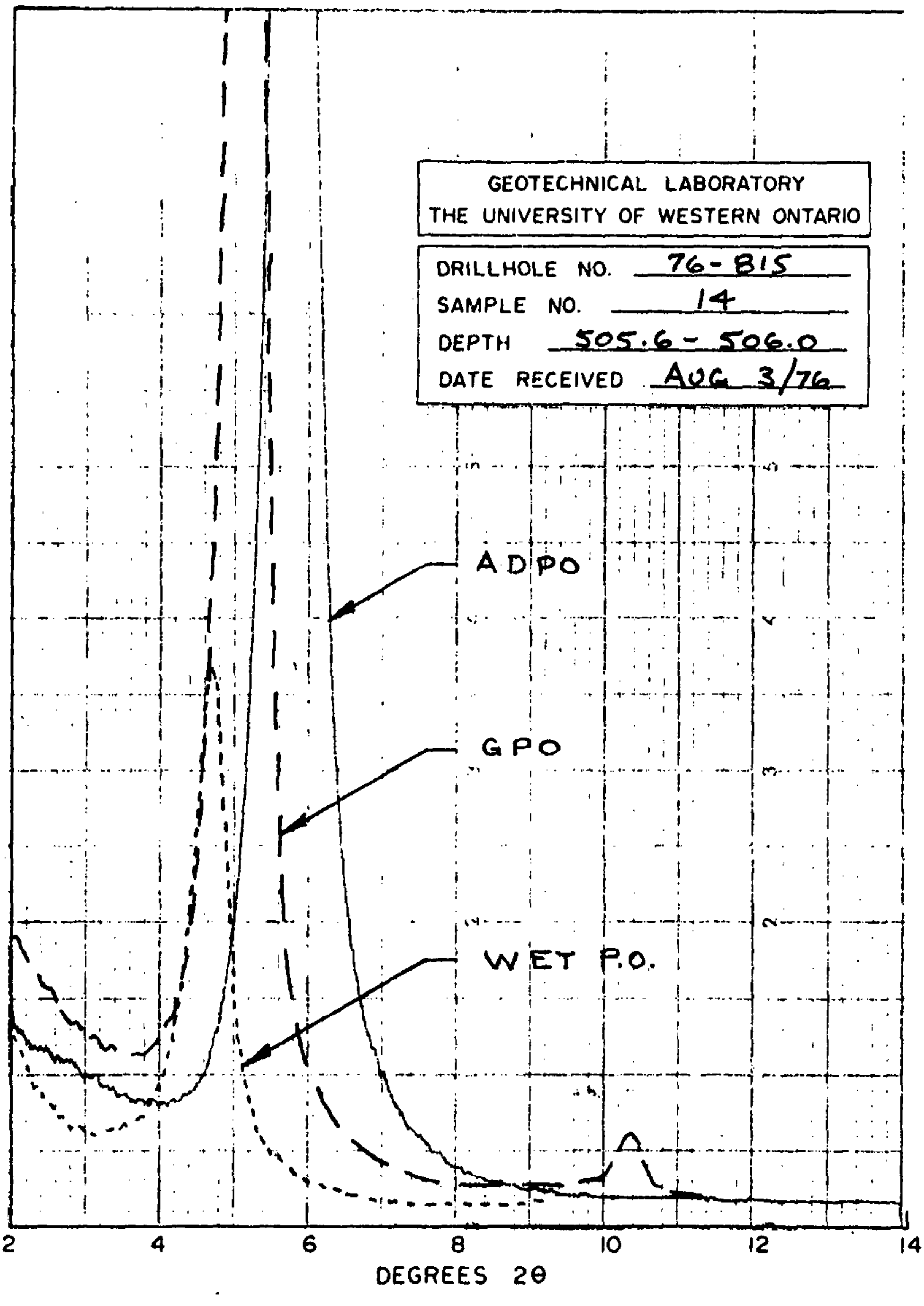

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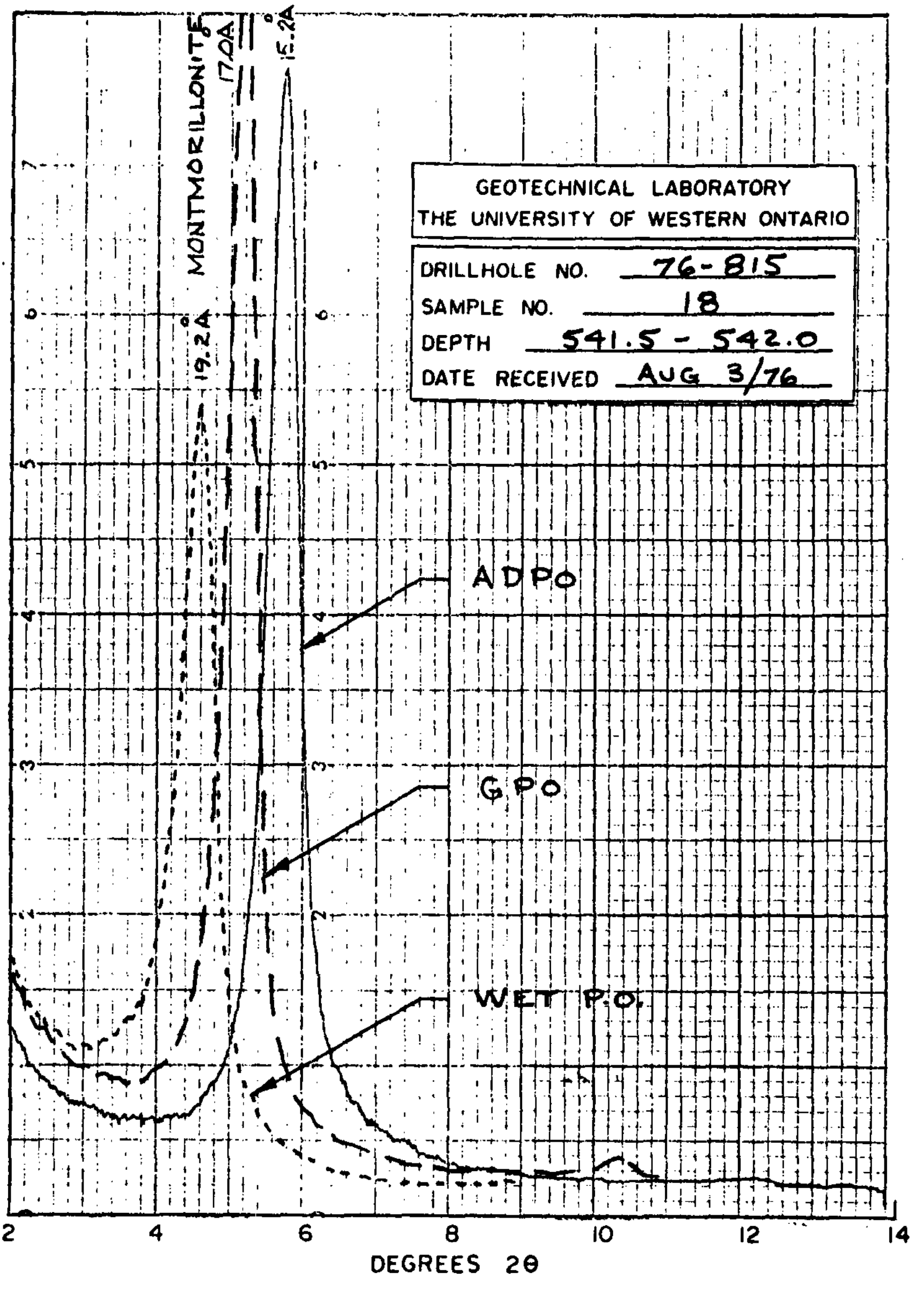

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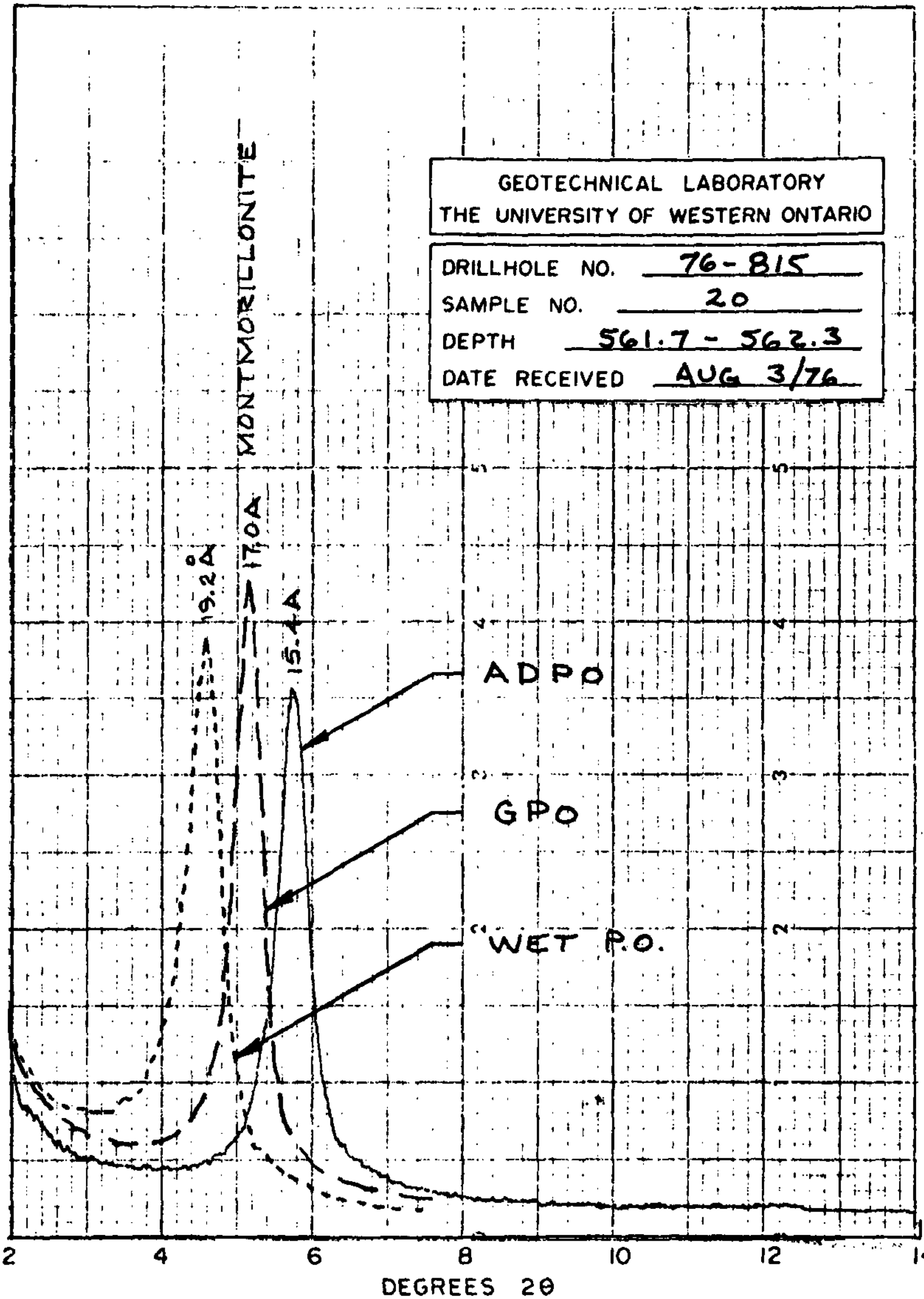

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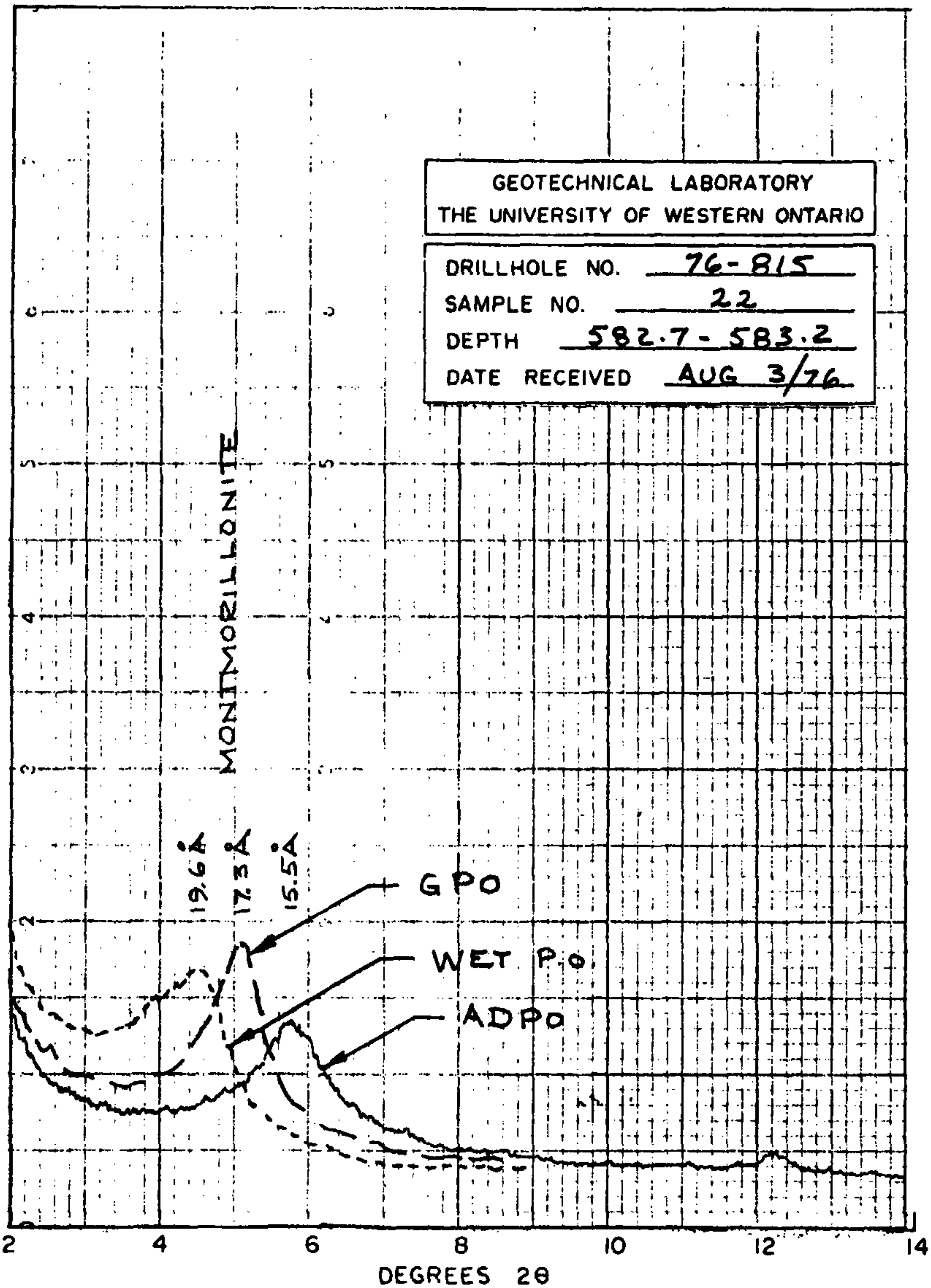

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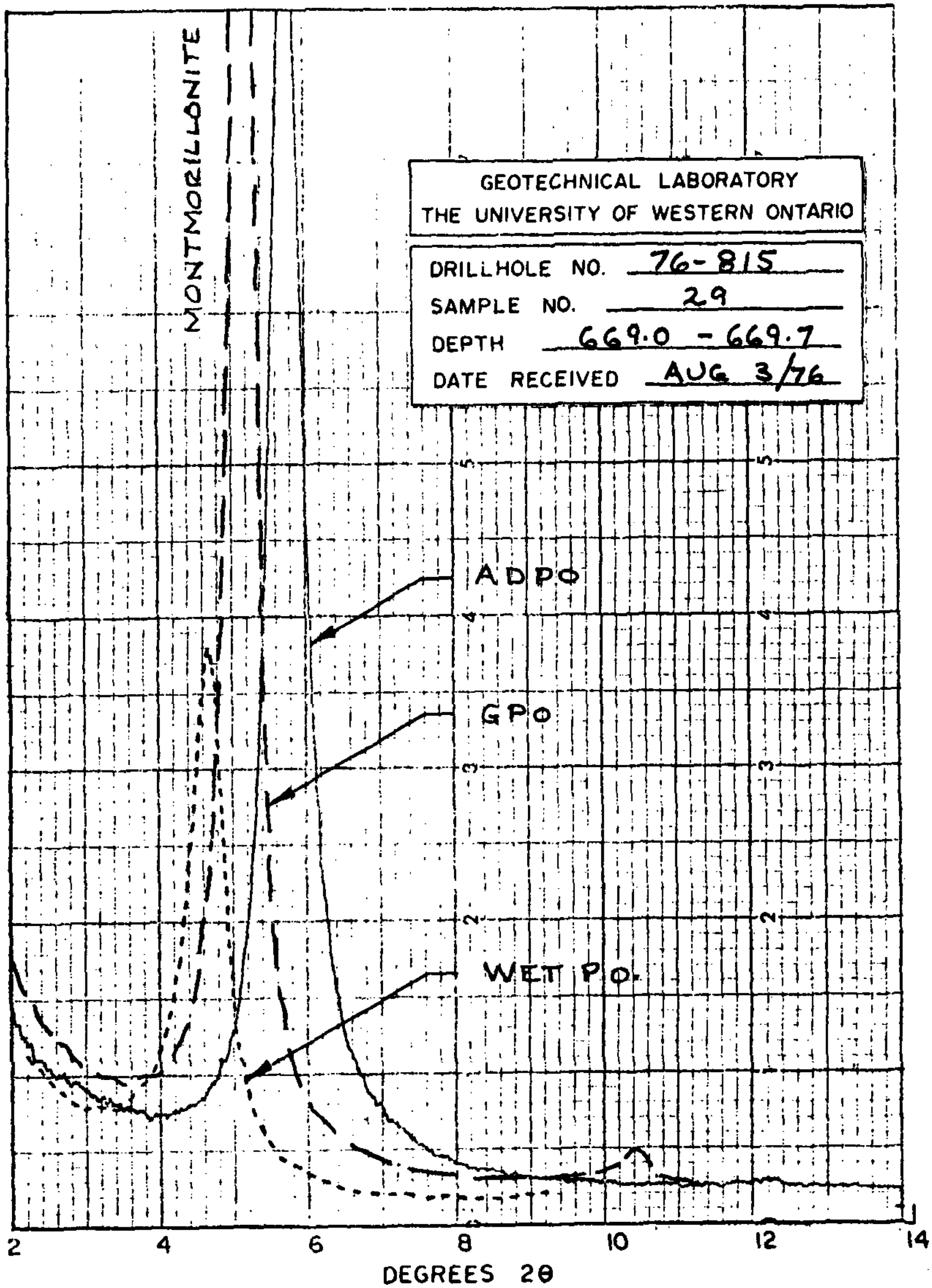


X-RAY DIFFRACTION TRACES OF 2 μ, PREFERRED ORIENTED SPECIMENS FROM HAT CREEK.

FEB 15 1977

FILE No.

The University of Western Ontario, London, Canada

Faculty of Engineering Science
London, Canada
N6A 5B9

7 September 1976

Mr. G. Rawlings
Golder, Brawner & Associates Ltd.
224 West 8th Avenue
Vancouver, British Columbia
V5Y 1N5

Dear Mr. Rawlings:

Report #4 - Hat Creek Project - Mineralogical Analyses
September 8, 1976

Enclosed are the x-ray and carbonate analyses on the last eight samples of Mr. Hawson's shipment of August 3, 1976.

On the basis of the cross-sections which you are sending to me, I will select samples for Na^+ and glycol retentions. As we discussed by phone today, I will call you prior to commencing this last phase of the testing.

Specific Comments on Present Samples

1. Carbonate is abundant only in sample 76-816.

2. Most of the samples consist of montmorillonite and feldspar with trace amounts of quartz.

3. Sample 76-809 (#2) may contain some cristobalite.

Yours sincerely,

R.M. Quigley

R.M. Quigley, P.Eng.
Professor of Geotechnical Engineering

RMQ:em
Encs.

cc: Mr. H.H. Hawson, Kamloops, B.C.

HAT CREEK PROJECT

LIST OF SAMPLES RECEIVED FROM GOLDER BRAWNER & ASSOCIATES

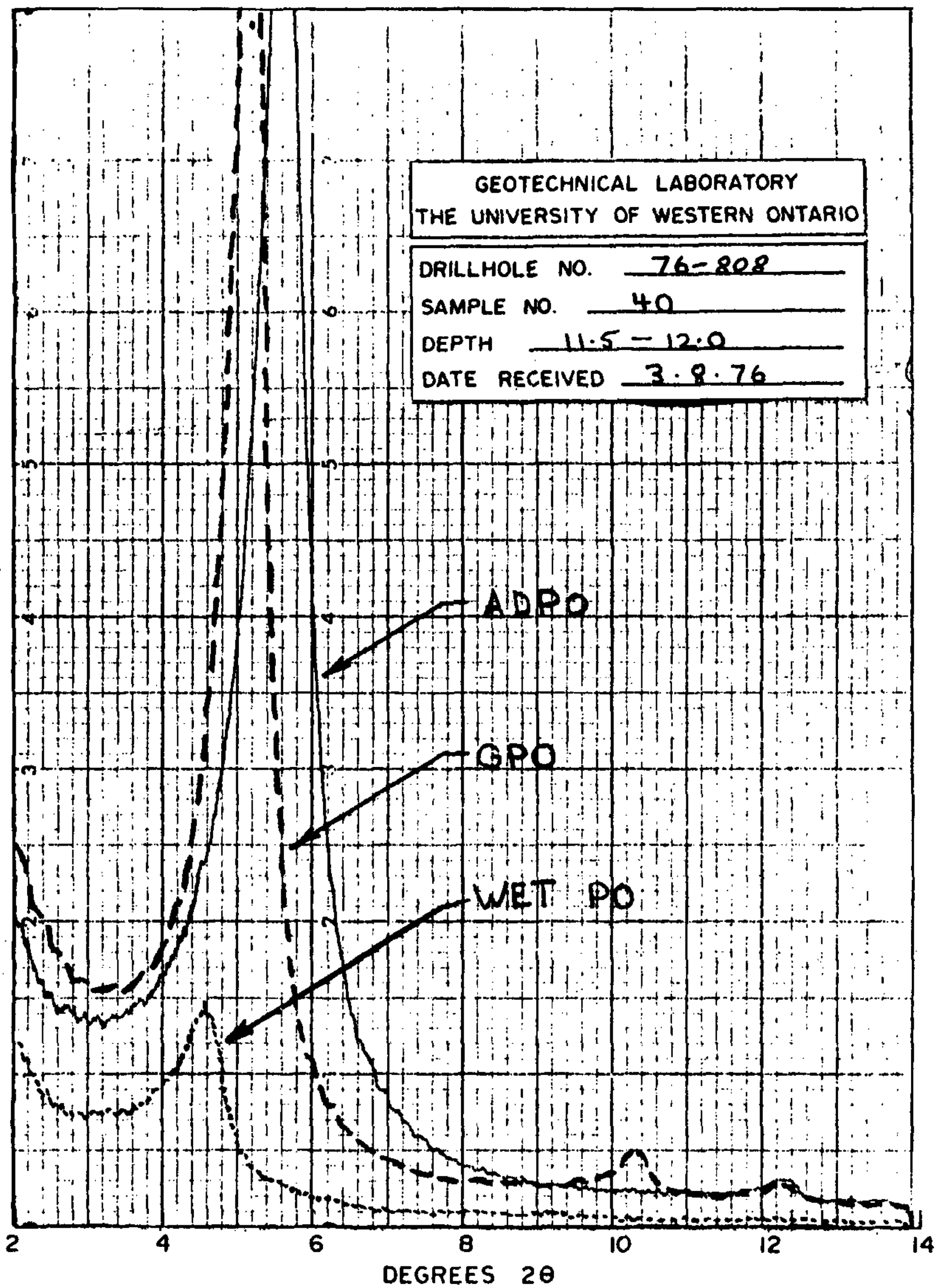
GEOTECHNICAL LABORATORY
THE UNIVERSITY OF WESTERN ONTARIO

Drill Hole No.	Sample No.	Depth (Feet)	Date Received	Testing Completed						
				X-ray				Carbonate (%)	Glycol Retention (mg/g)	Na^+ ppm
				Wet P.O.	ADPO	GPO	Powder			
76-808	40	11.5 - 12.0	AUG 3/76	✓	✓	✓	✓	3.0		
76-808	10	30.8 - 33.3	AUG 3/76	✓	✓	✓	✓	1.7		
76-809	2	14.8 - 16.0	AUG 3/76	✓	✓	✓	✓	2.6		
76-809	4	32.6 - 33.8	AUG 3/76	✓	✓	✓	✓	2.7		
76-816	19	472.9 - 473.7	AUG 3/76	✓	✓	✓	✓	30.7		
SLIDE HEADWALL	T1		AUG 3/76	✓	✓	✓	✓	2.8		
SLIDE HEADWALL	T2		AUG 3/76	✓	✓	✓	✓	3.8		
SLIDE HEADWALL	T3		AUG 3/76	✓	✓	✓	✓	4.2		

REPORT # 4

R. M. Quigley

Nov. 8, 1976



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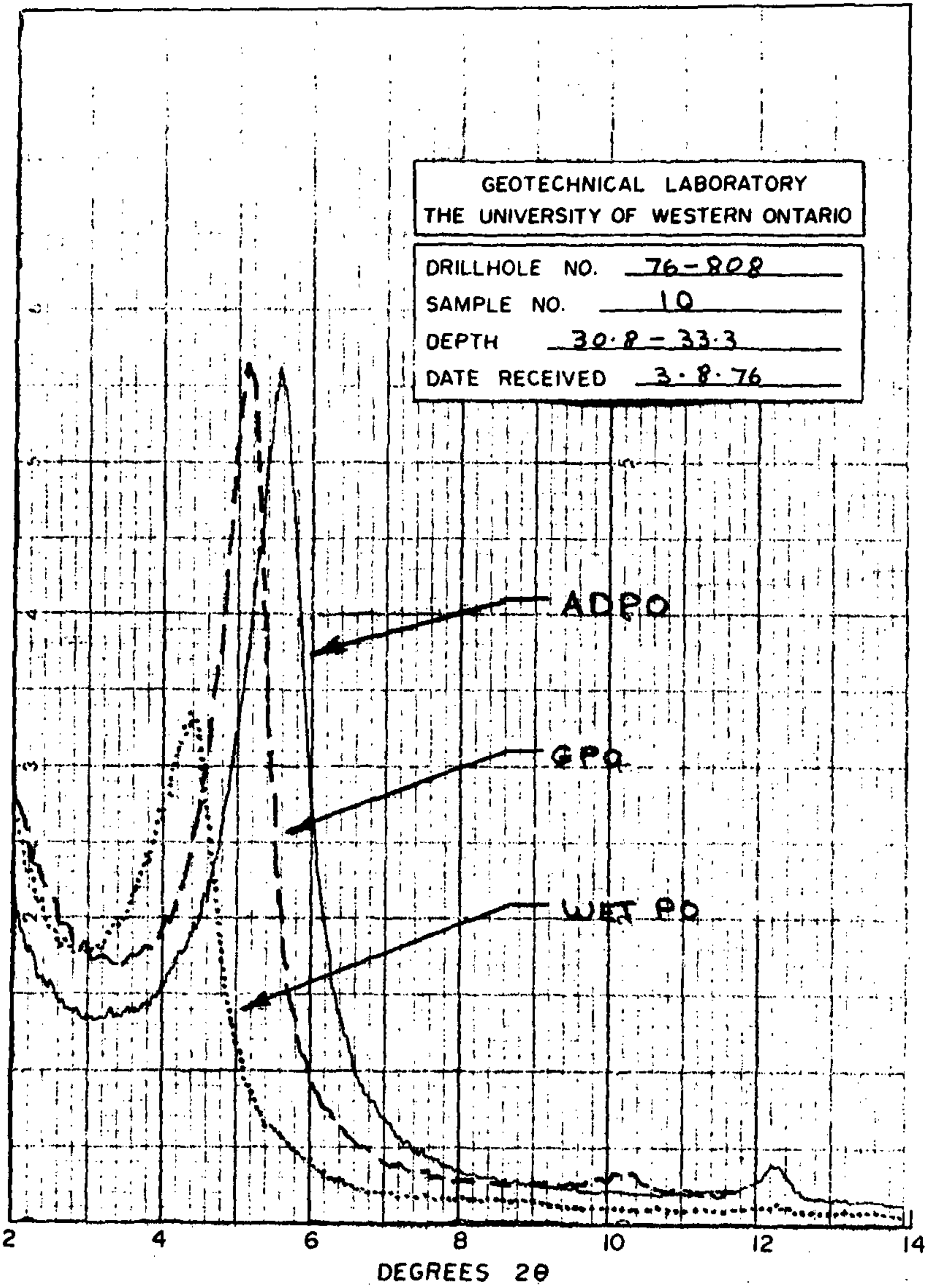

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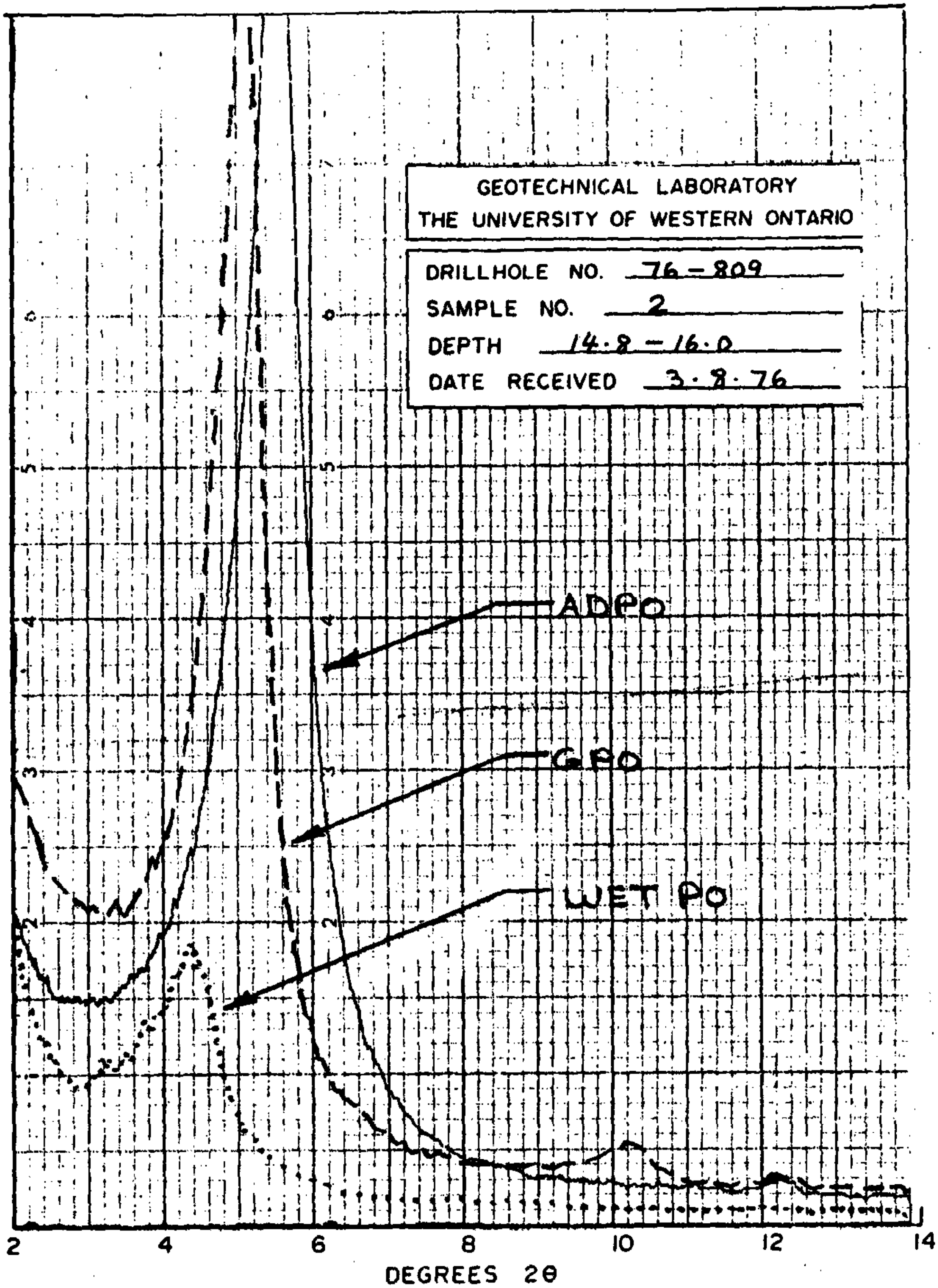

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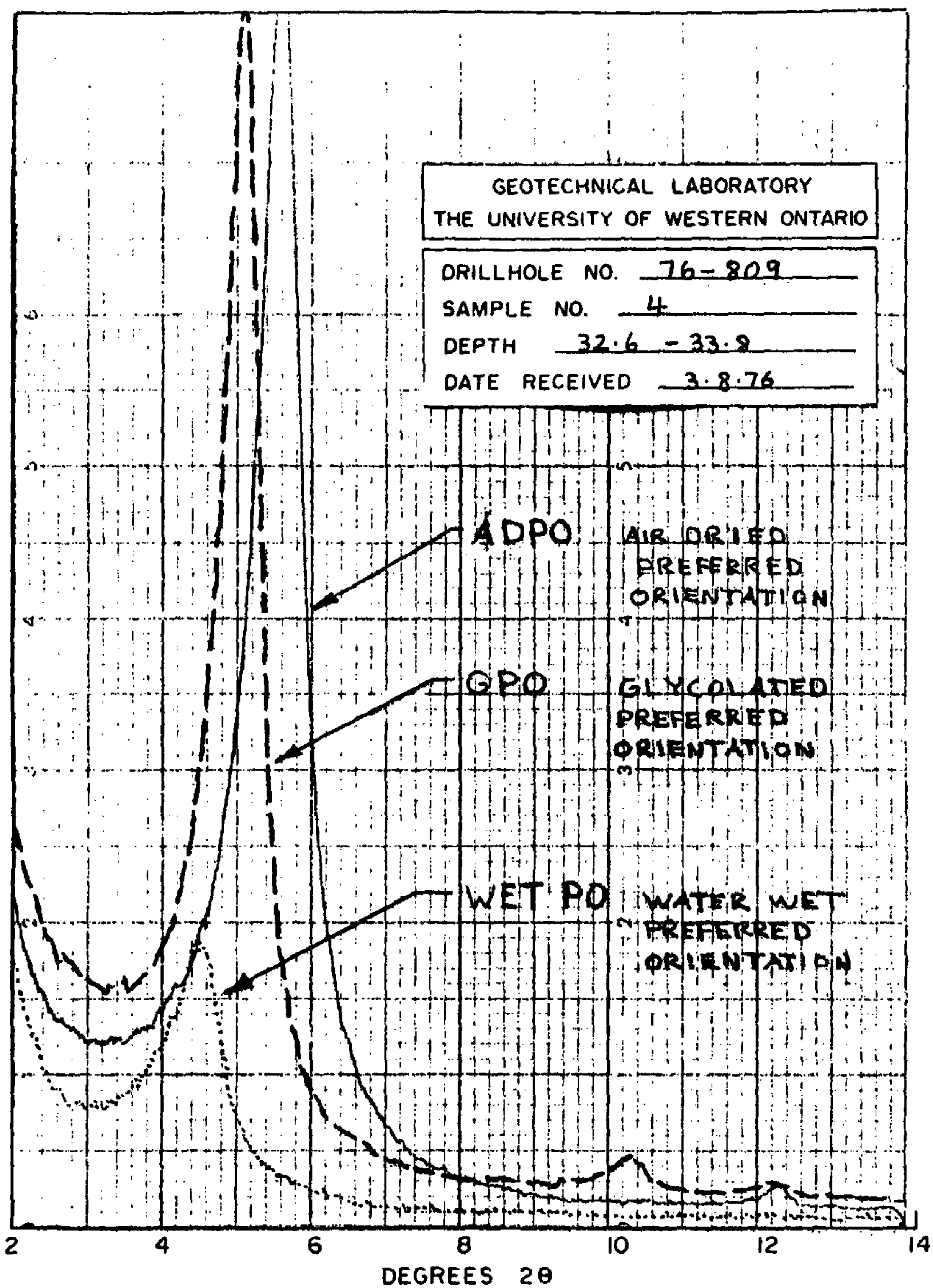

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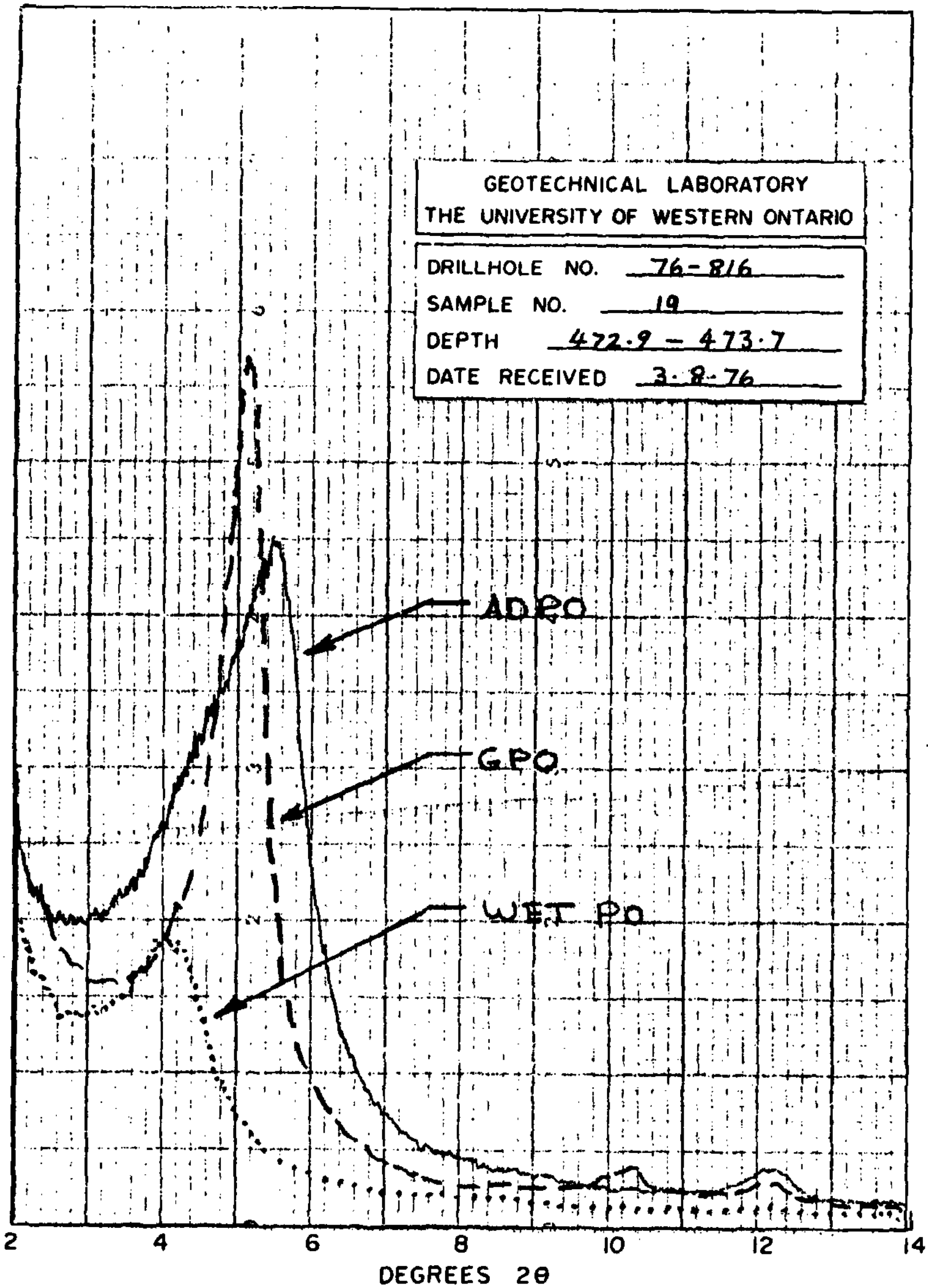

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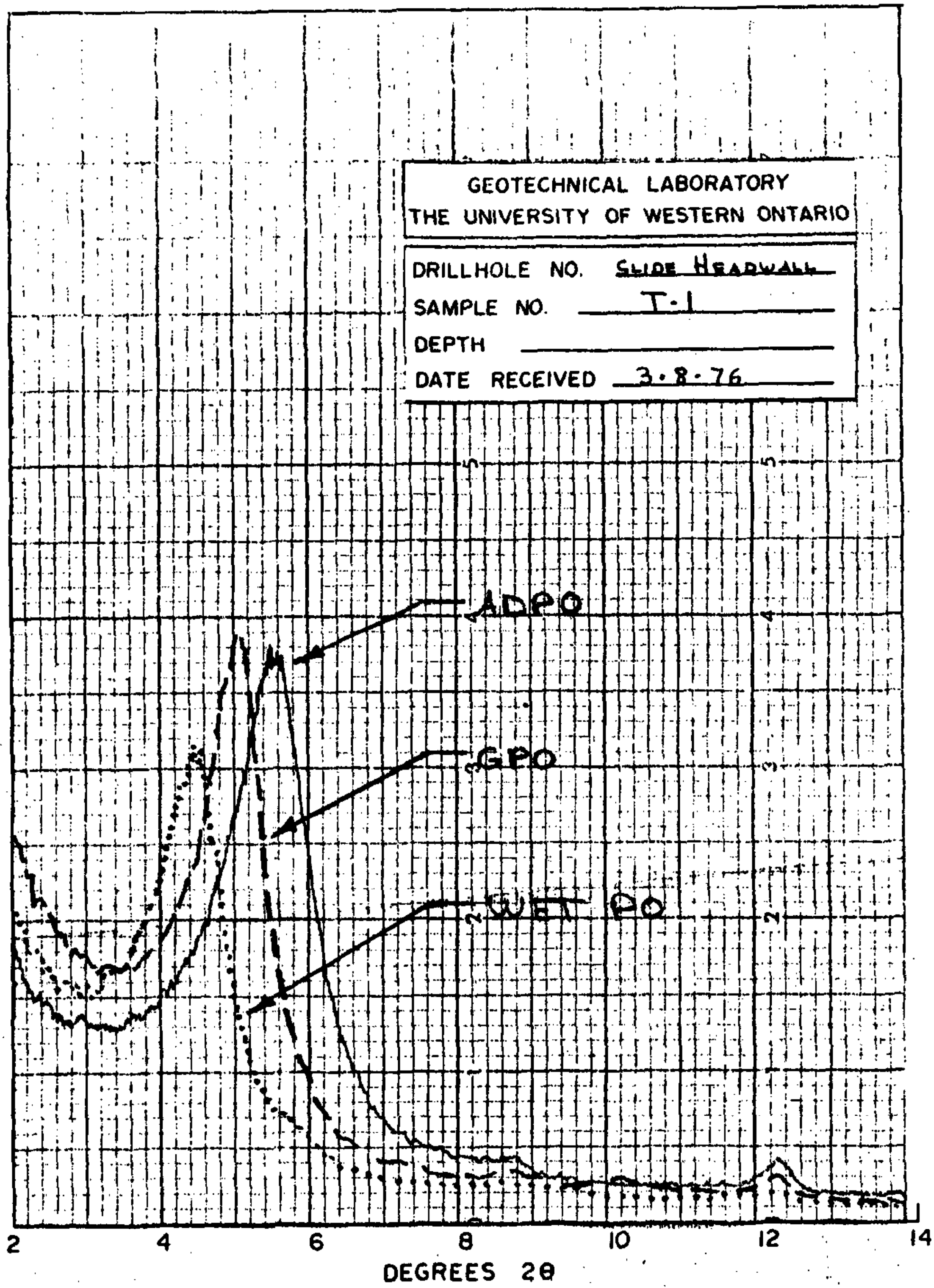

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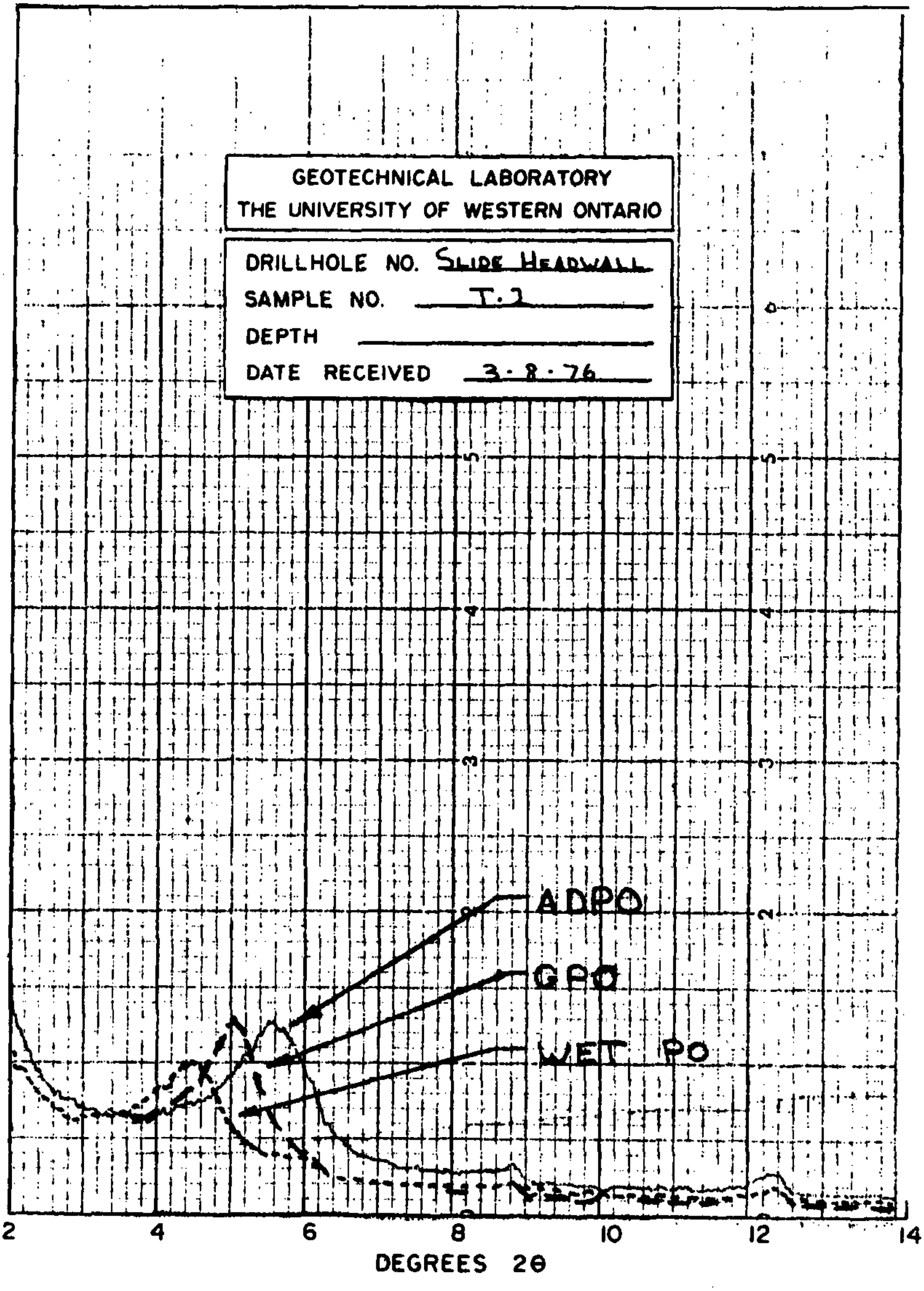

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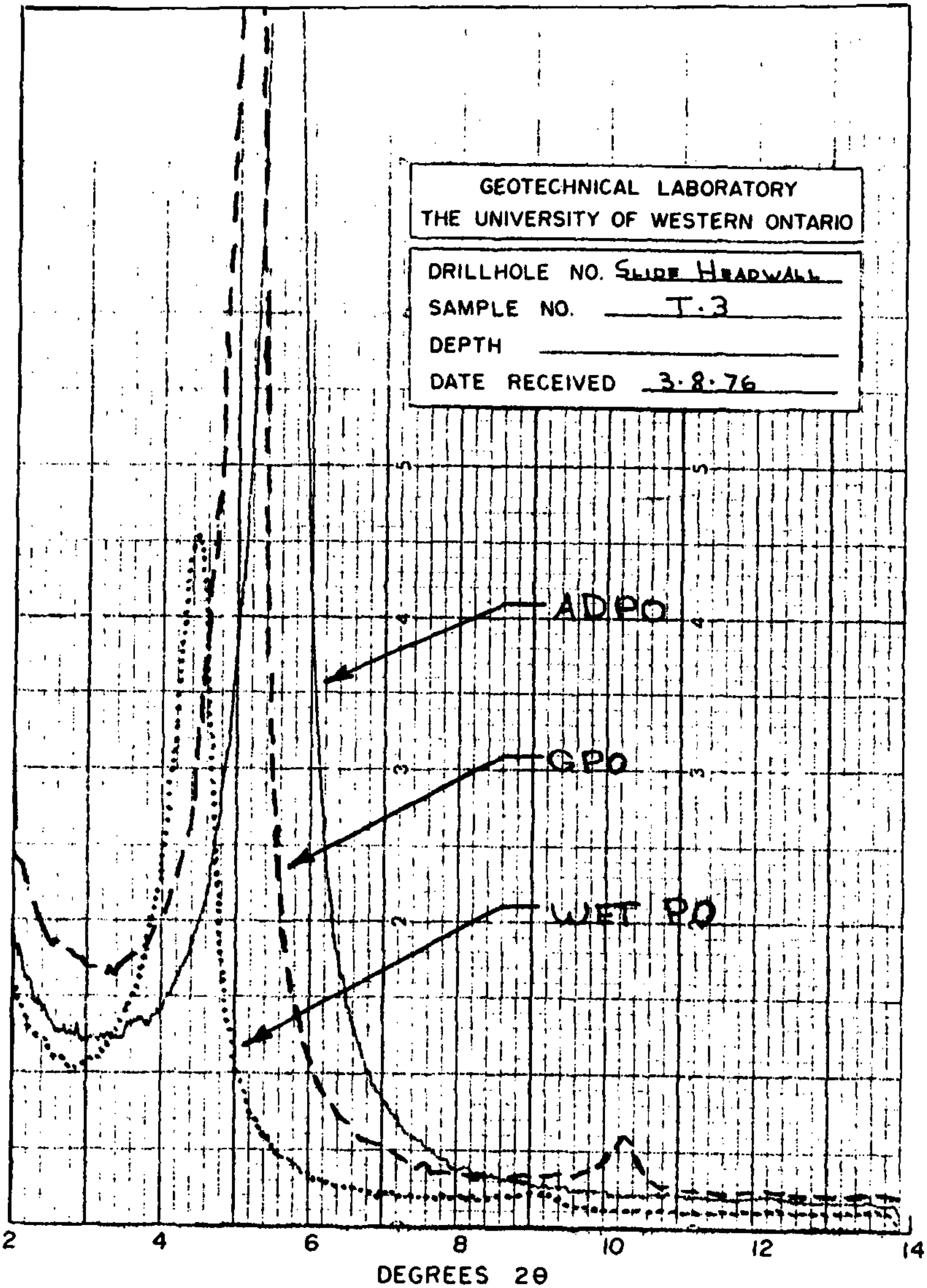

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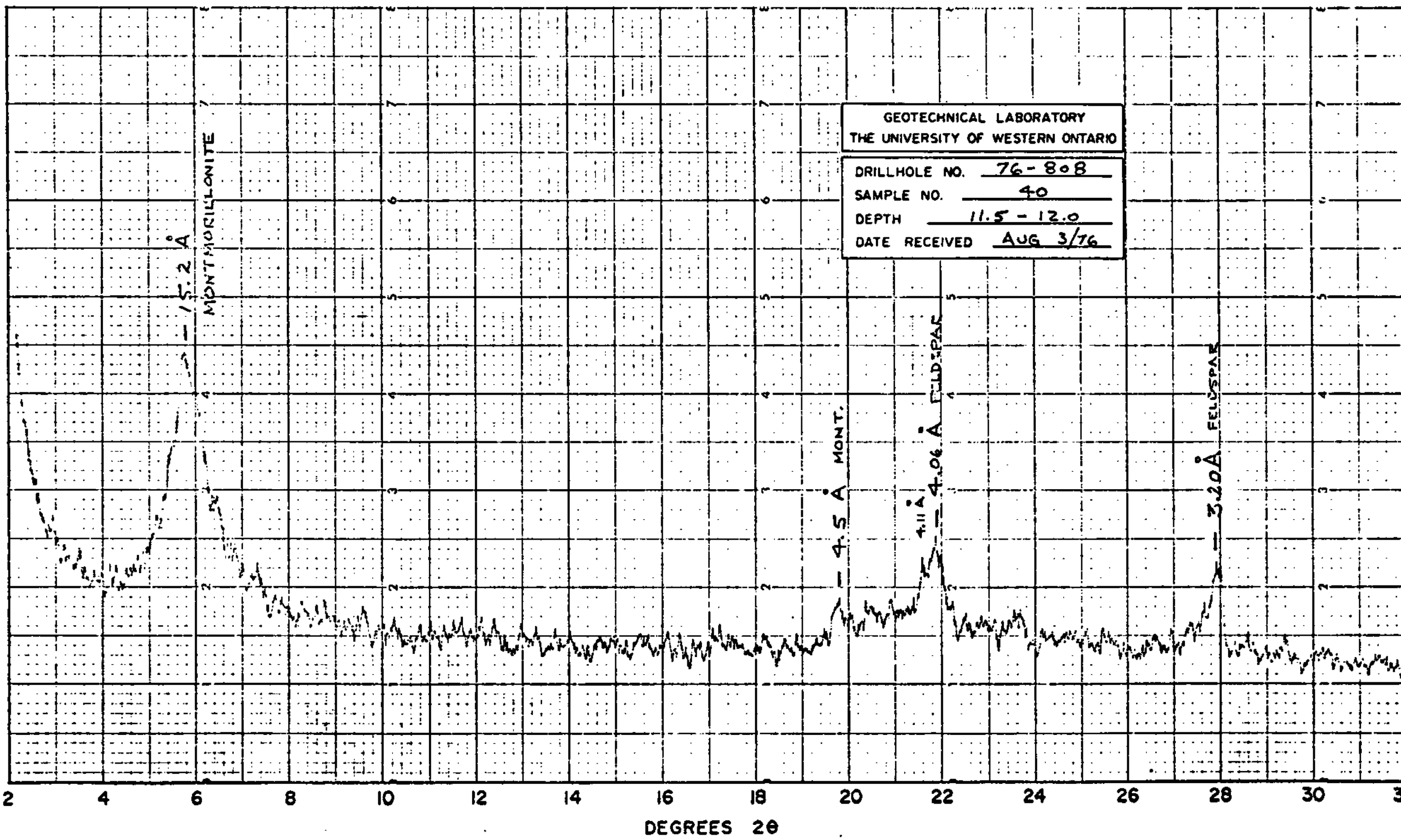

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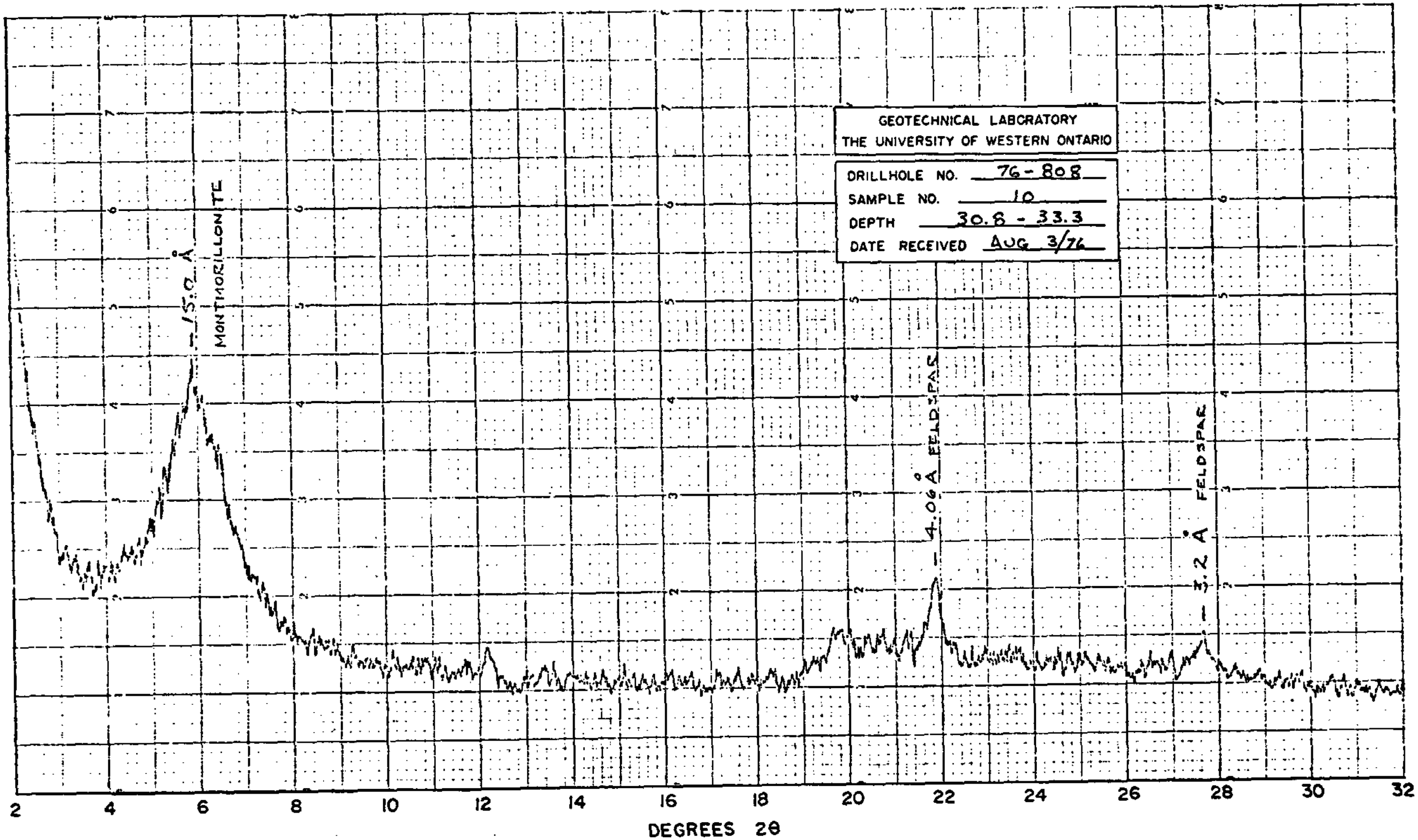

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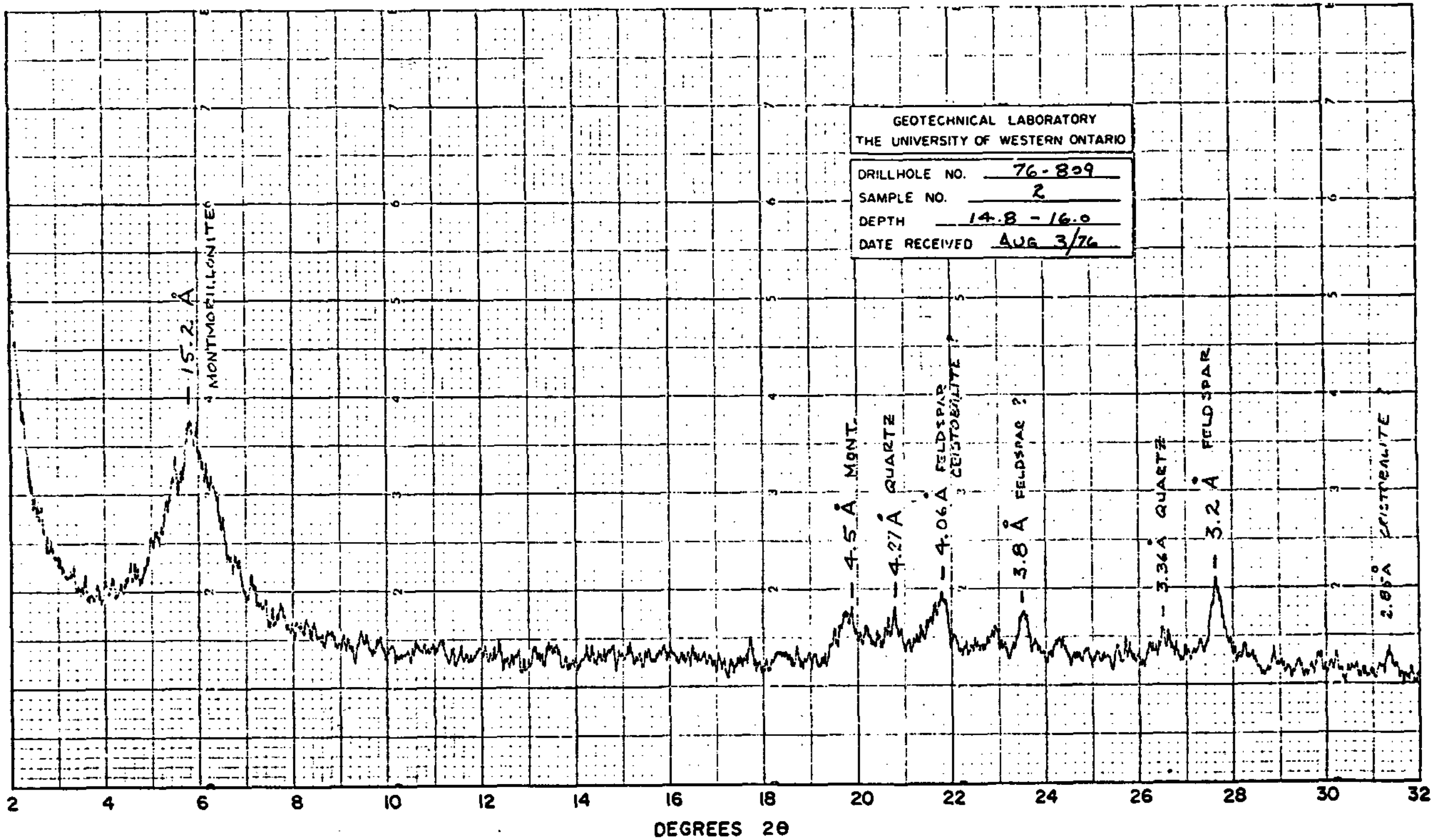

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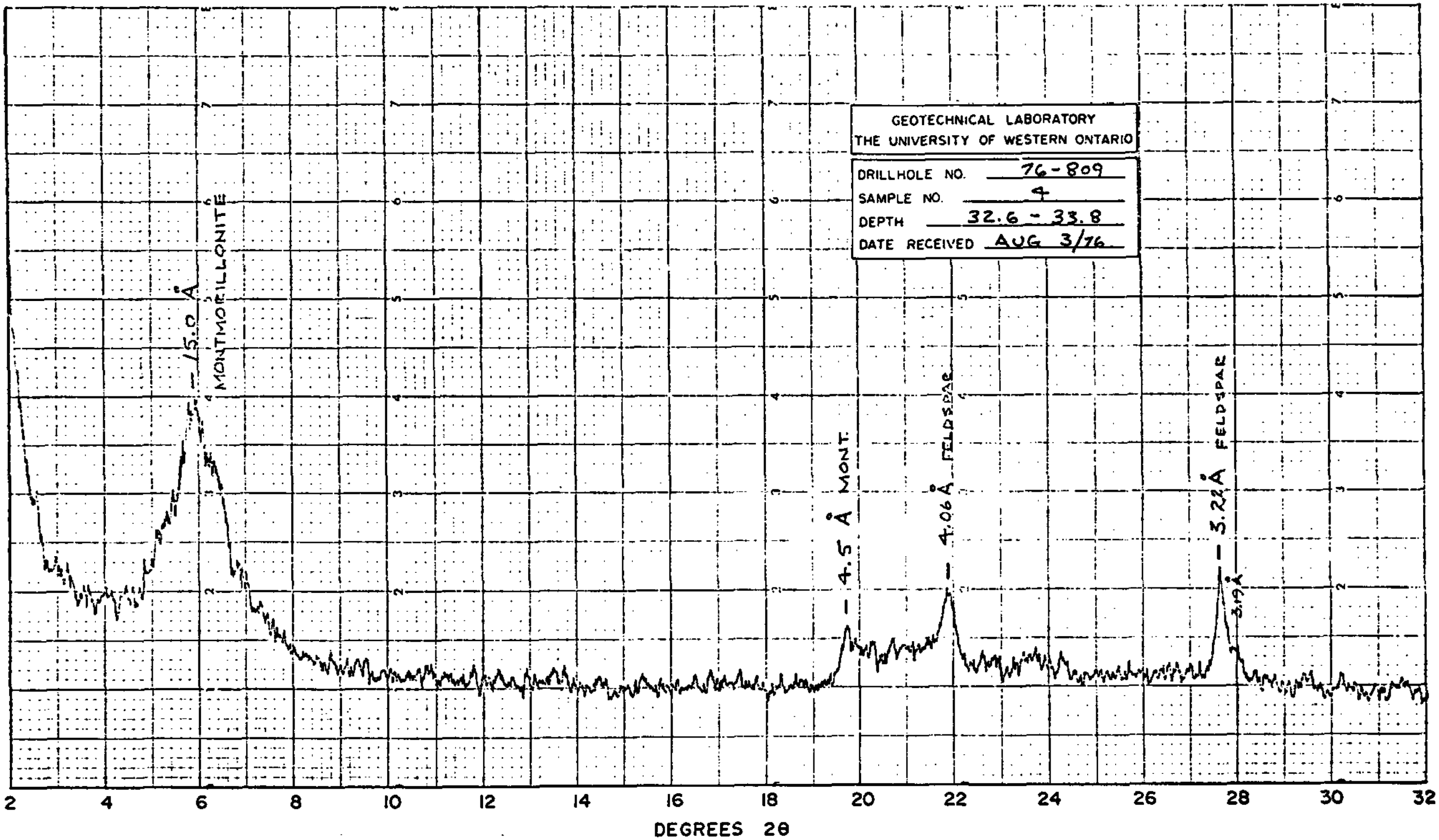

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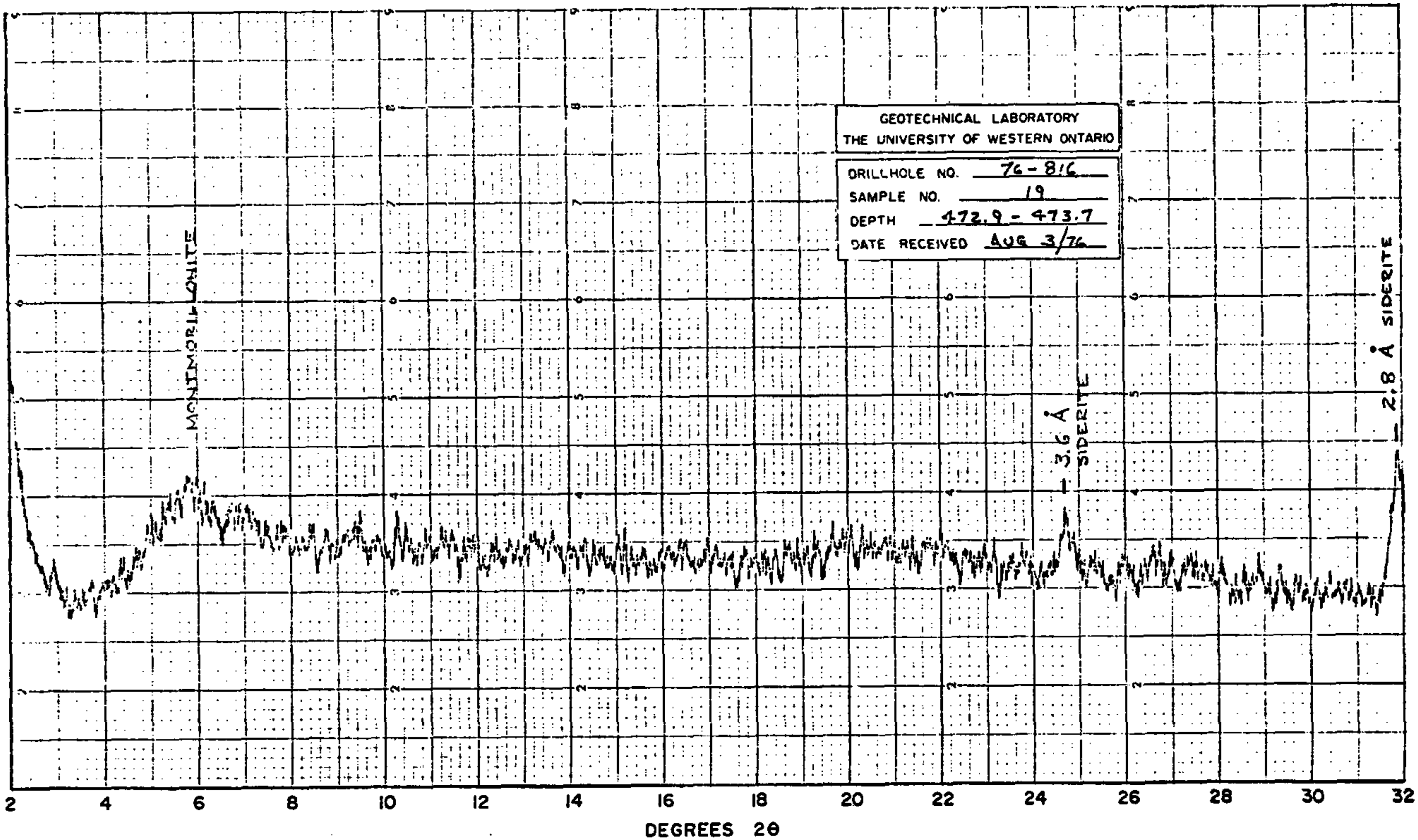

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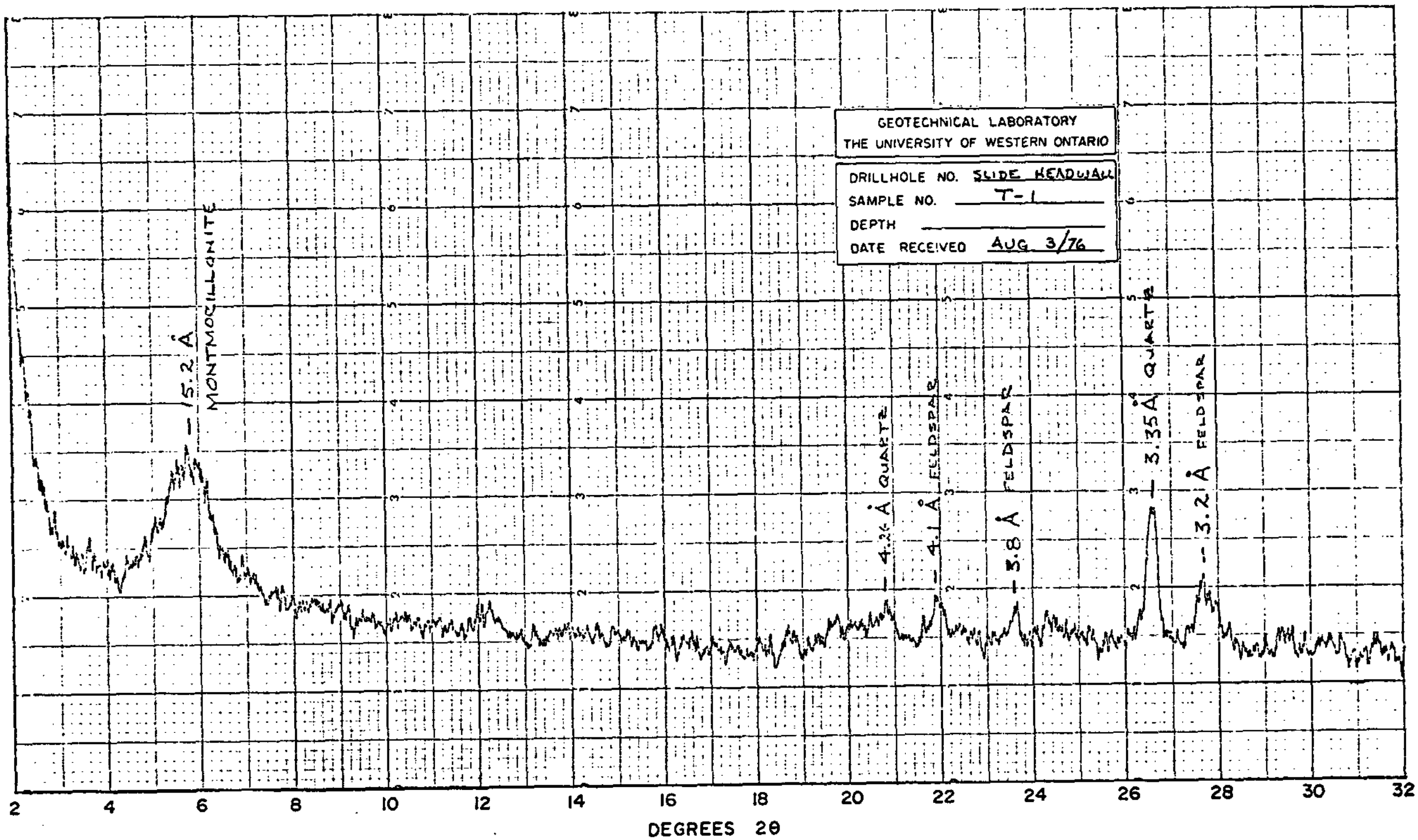

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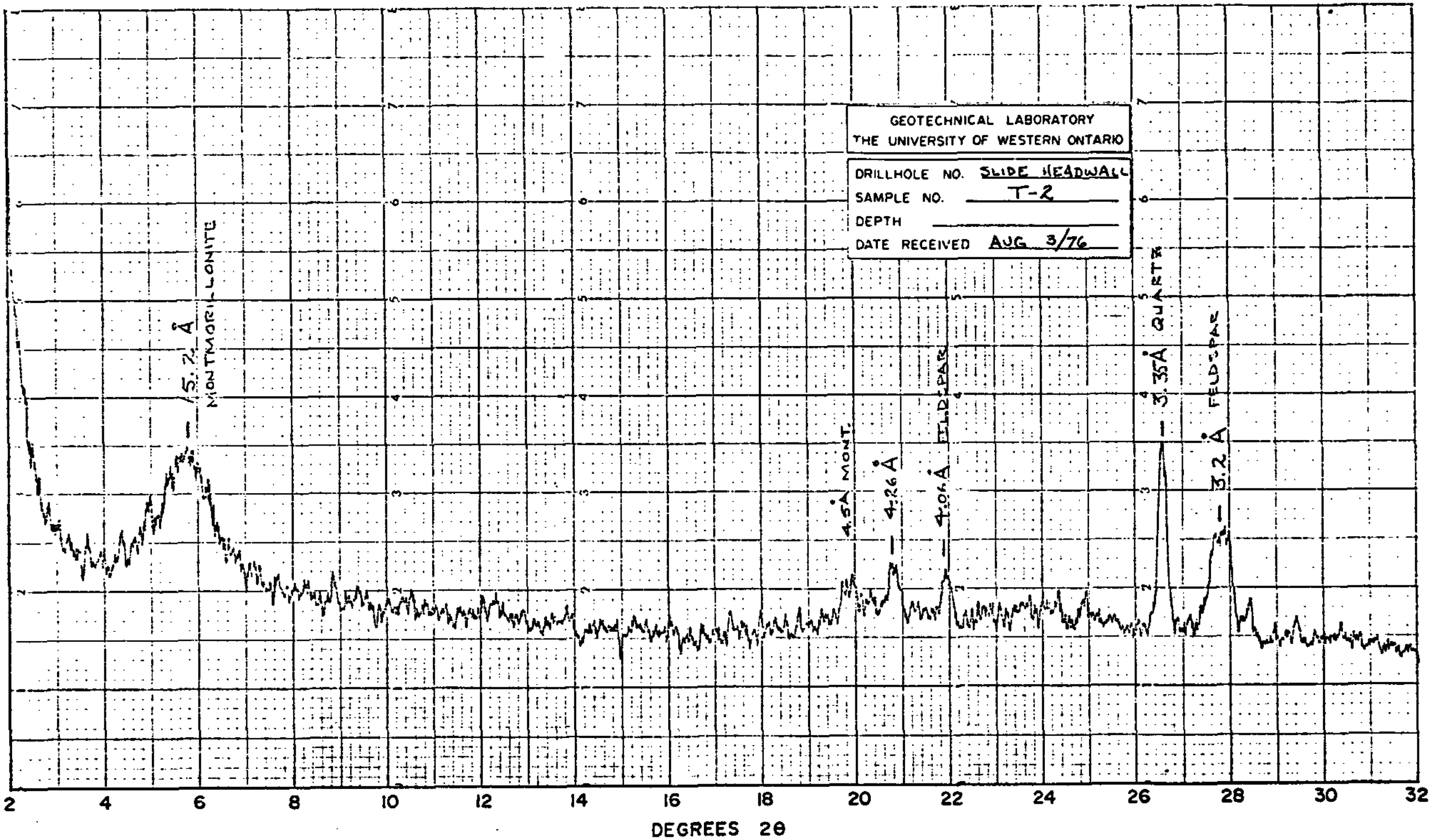

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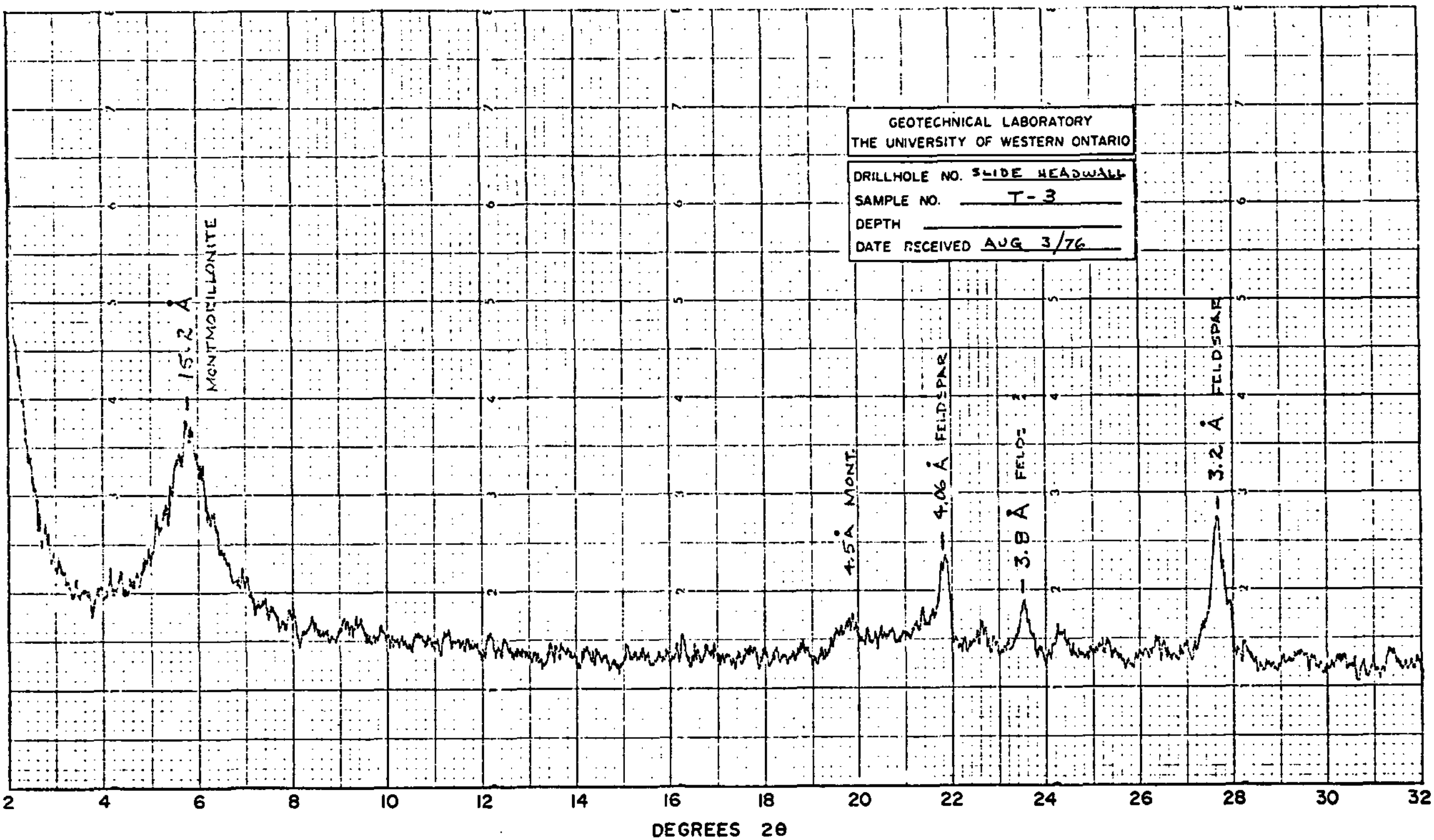


X-RAY DIFFRACTION TRACES OF WHOLE SOIL POWDERS FROM HAT CREEK.

FEB 15 .7//

FILE No

The University of Western Ontario, London, Canada

Faculty of Engineering Science
London, Canada
N6A 5B9

8 October 1976

Mr. G. Rawlings
Golder, Brawner & Associates Ltd.
224 West 8th Avenue
Vancouver, British Columbia
V5Y 1N5

Dear Mr. Rawlings:

Report #5 - Hat Creek Project - Mineralogical Analyses
October 8, 1976

Enclosed are the x-ray and carbonate analyses on the ten samples received on September 22, 1976. These samples were generally fairly soft and waxy or soapy looking, indicating abundant contained montmorillonite.

Specific Comments on the Samples

1. Carbonate is significant only in sample 74-27-1 from 569.5 feet depth, which contained about 60.4% siderite by Chittick analysis and yielded a large 2.80 Å peak on the x-ray powder pattern.
2. The rest of the powder patterns are characterized by large (001) montmorillonite peaks and moderate to minor amounts of feldspar and quartz.
3. The x-ray traces of the oriented minus 2 μm fractions indicate montmorillonite with a degree of non-regular basal spacing not noted in previous samples. This is particularly true of the wet preferred orientation traces which show only a high background above 19.6 Å. It is probable that this represents a greater degree of hydration by water and interlayer swelling than was observed for the previous samples.

Since we have not yet received cross sections of the site upon which to base our selection of samples for the glycol retention analyses, we will defer these until after our discussions in Vancouver.

Yours sincerely,

R.M. Quigley

R.M. Quigley, P.Eng.
Professor of Geotechnical Engineering

RMQ:em

cc: Mr. H.H. Hawson
Kamloops, B.C.

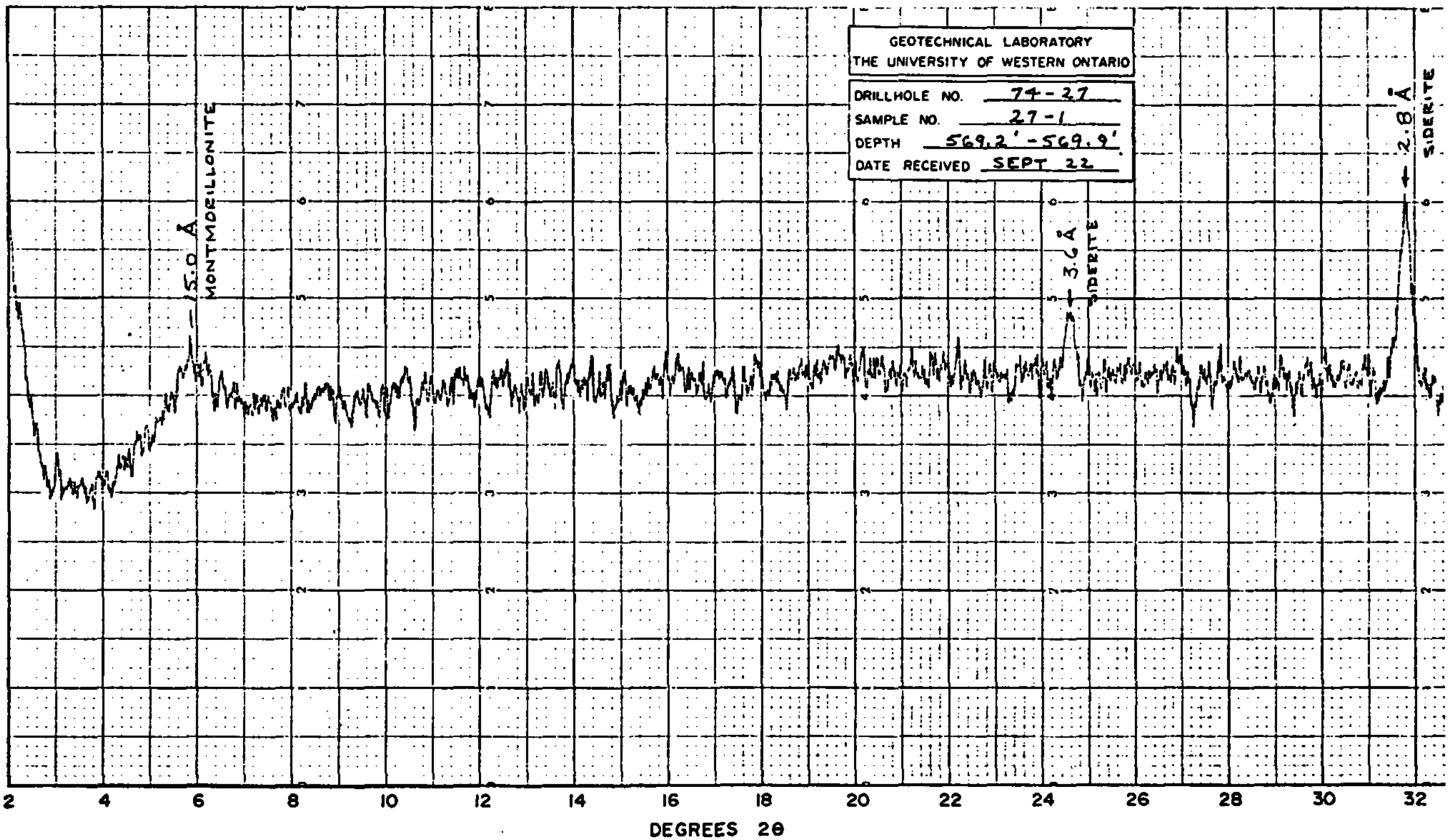
HAT CREEK PROJECT LIST OF SAMPLES RECEIVED FROM GOLDER BRAWNER & ASSOCIATES	GEOTECHNICAL LABORATORY THE UNIVERSITY OF WESTERN ONTARIO

Drill Hole No.	Sample No.	Depth (Feet)	Date Received	Testing Completed						
				X-ray				Carbonate (%)	Glycol Retention (mg/g)	Na^+ (PPM)
				Wet P.O.	ADPO	GPO	Powder			
74-27	27-1	569.2-569.9	SEPT 22	✓	✓	✓	✓	60.4		
76-806	-	135.0-135.6	SEPT 22	✓	✓	✓	✓	2.5		
76-806	-	325.0-325.5	SEPT 22	✓	✓	✓	✓	2.1		
76-808	-	276.0-276.5	SEPT 22	✓	✓	✓	✓	2.7		
76-808	-	392.0-392.6	SEPT 22	✓	✓	✓	✓	1.5		
76-811	5	41.5-42.5	SEPT 22	✓	✓	✓	✓	1.3		
76-811	-	112.5-113.0	SEPT 22	✓	✓	✓	✓	4.5		
76-811	-	176.5-177.0	SEPT 22	✓	✓	✓	✓	2.5		
76-812	43	157.0	SEPT 22	✓	✓	✓	✓	2.2		
76-818	4	28.3-29.6	SEPT 22	✓	✓	✓	✓	2.4		

REPORT #5

R. M. Quigley

Oct. 8/76



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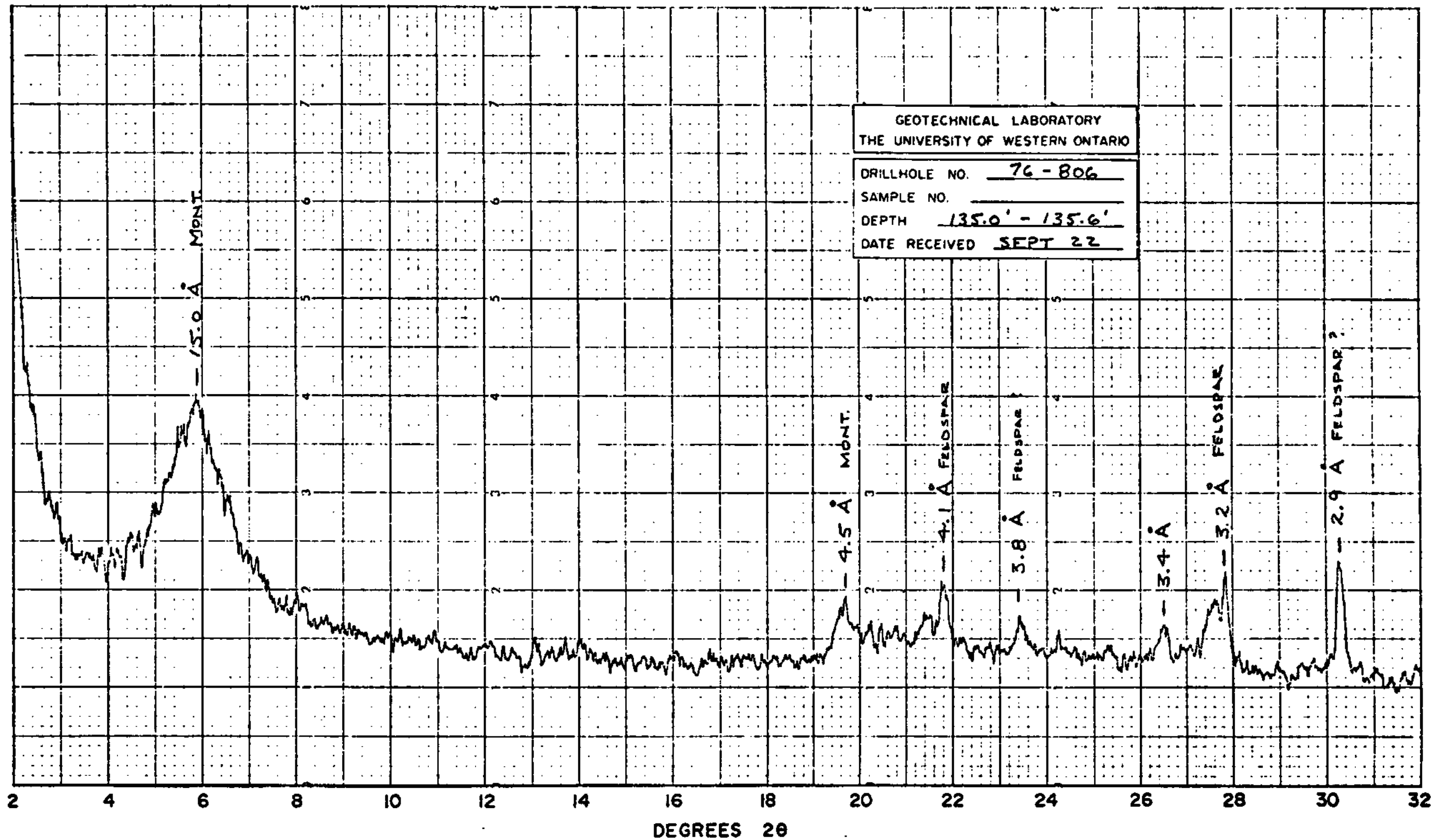

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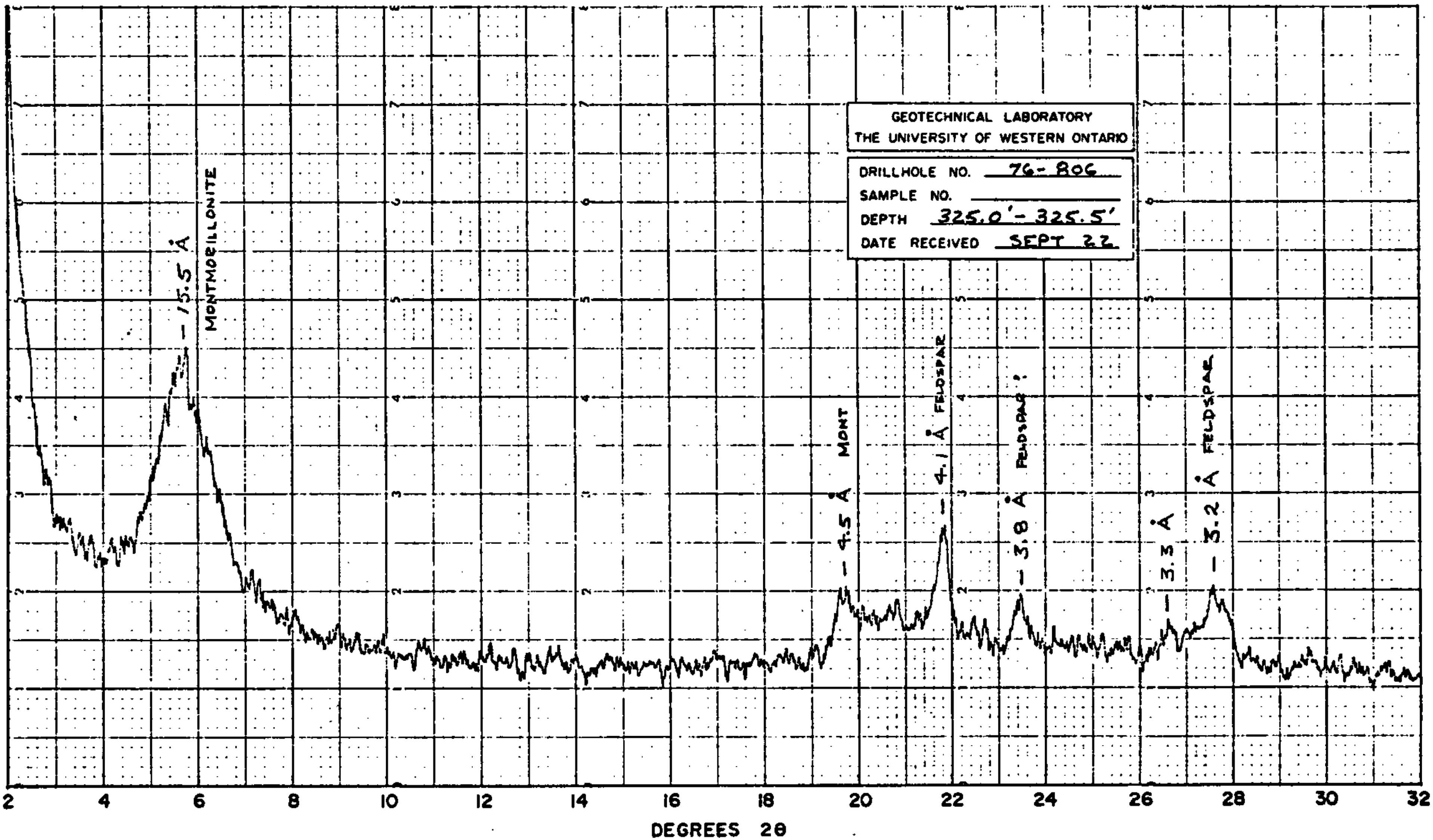

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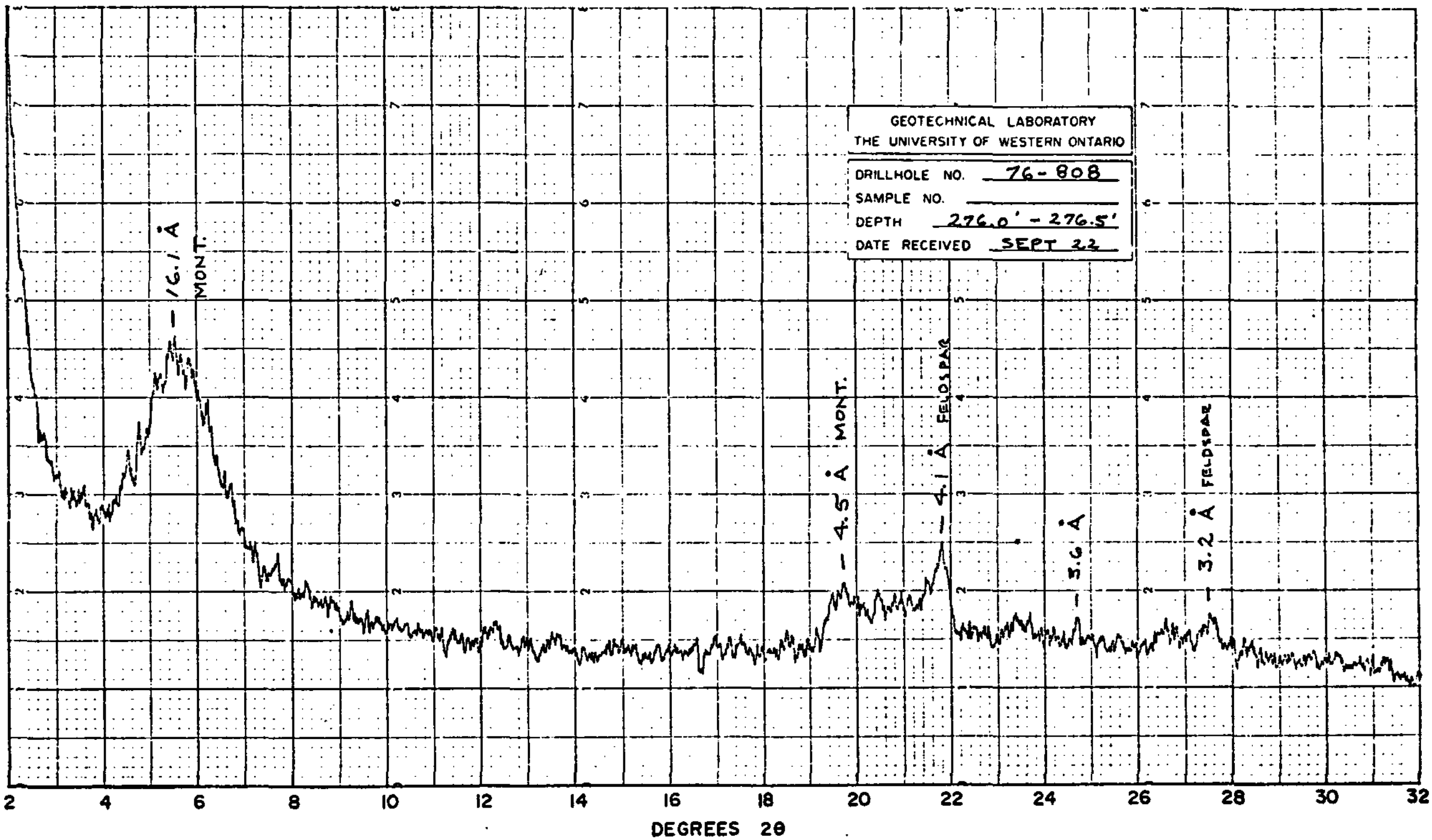

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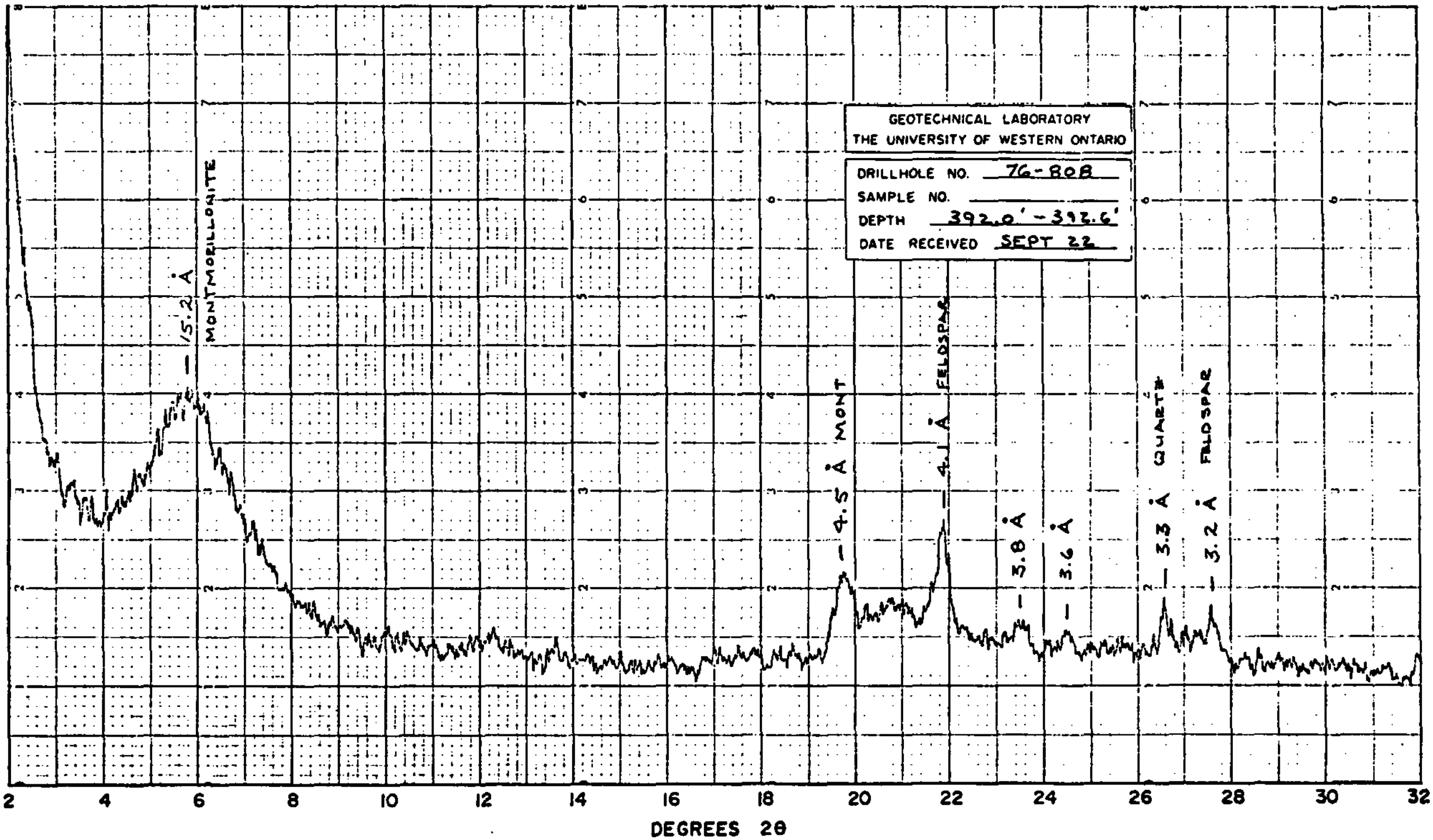

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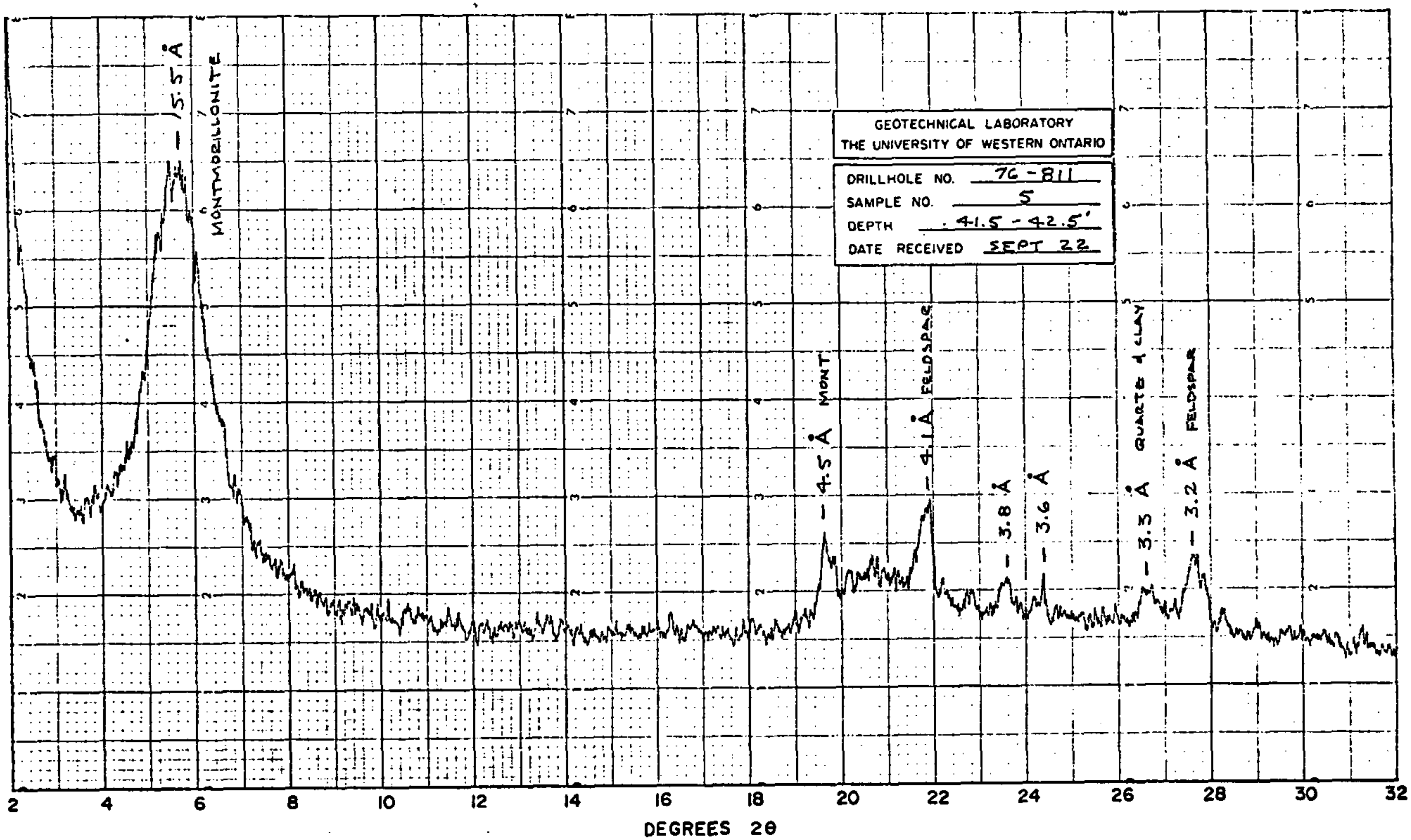

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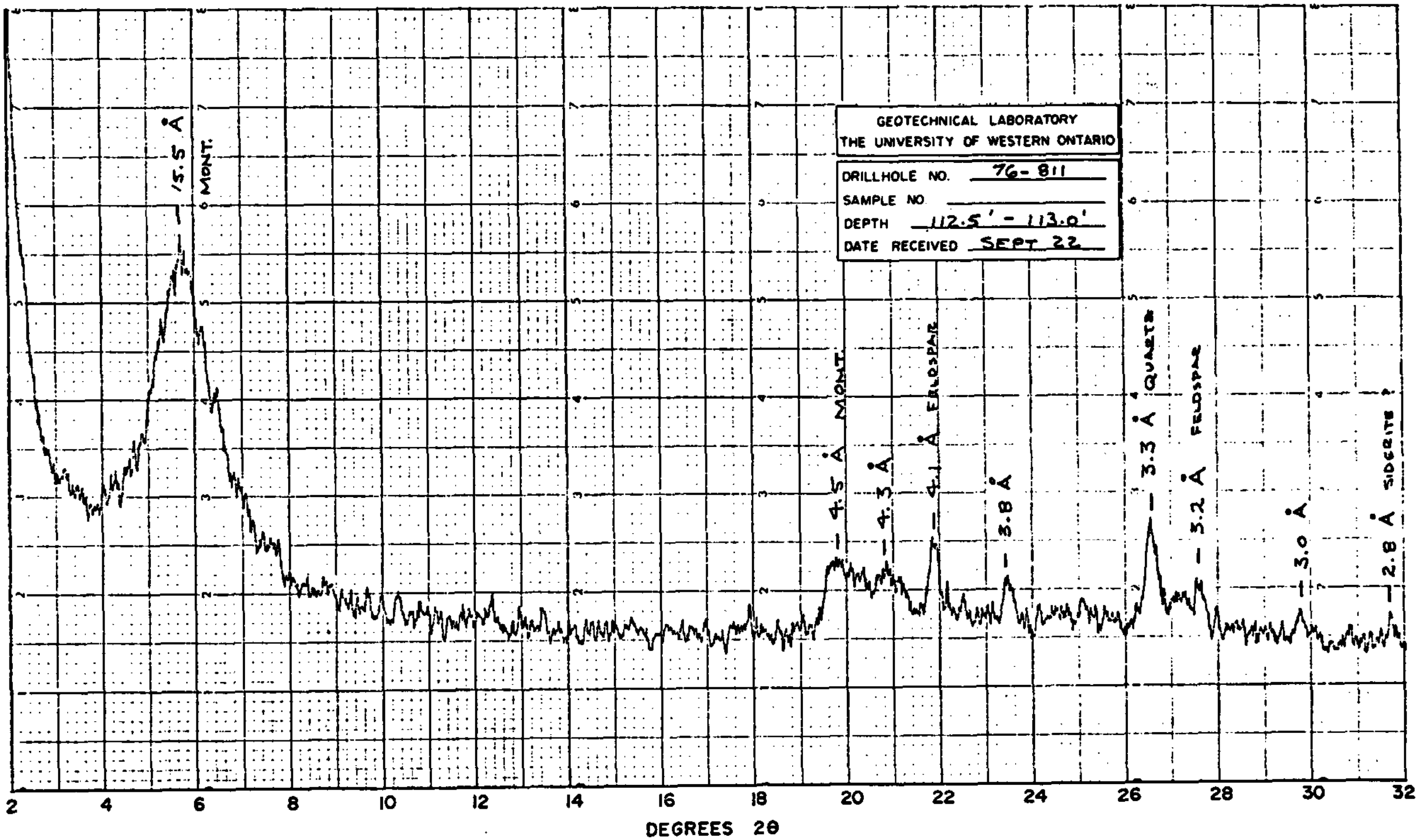

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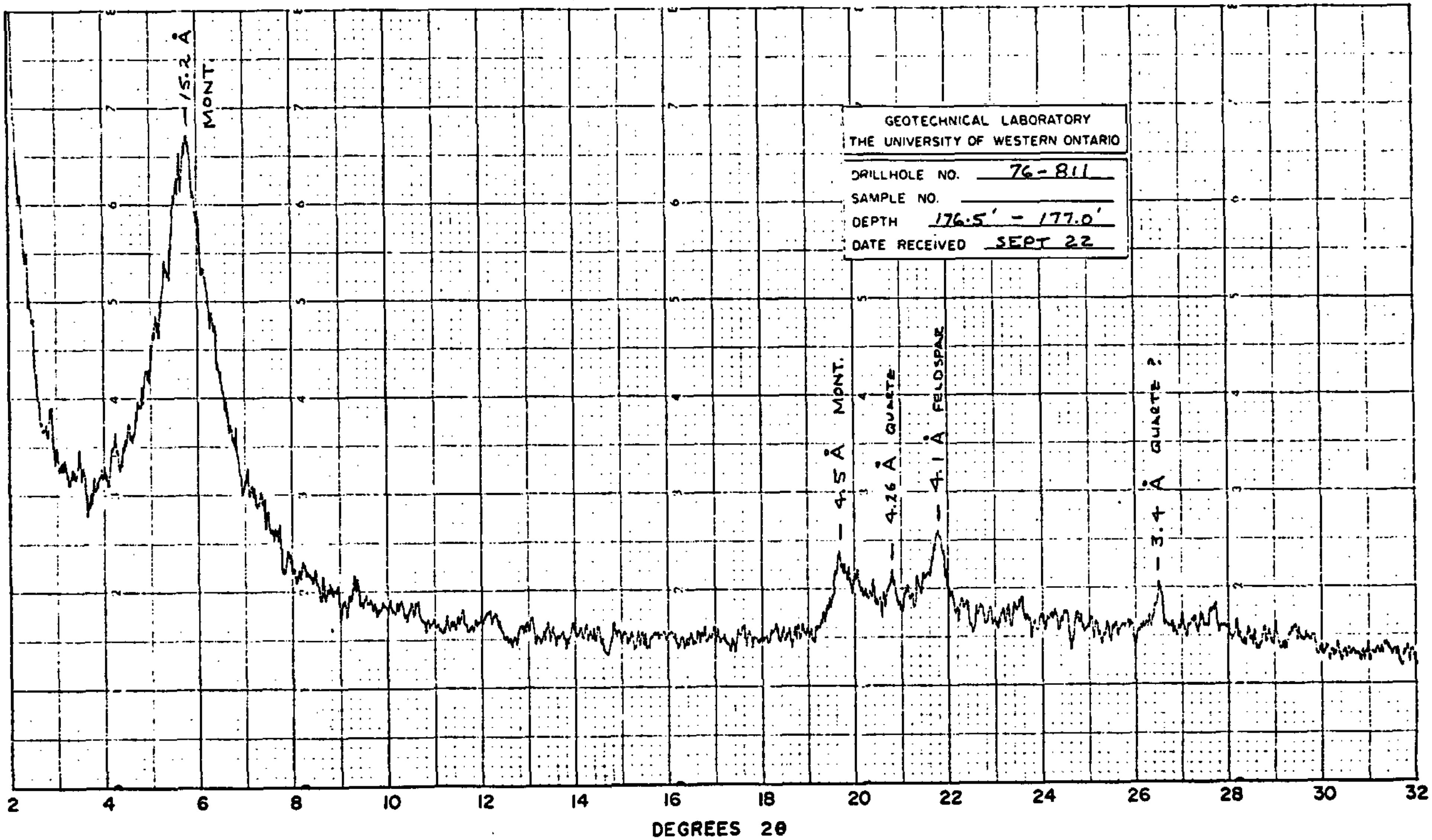

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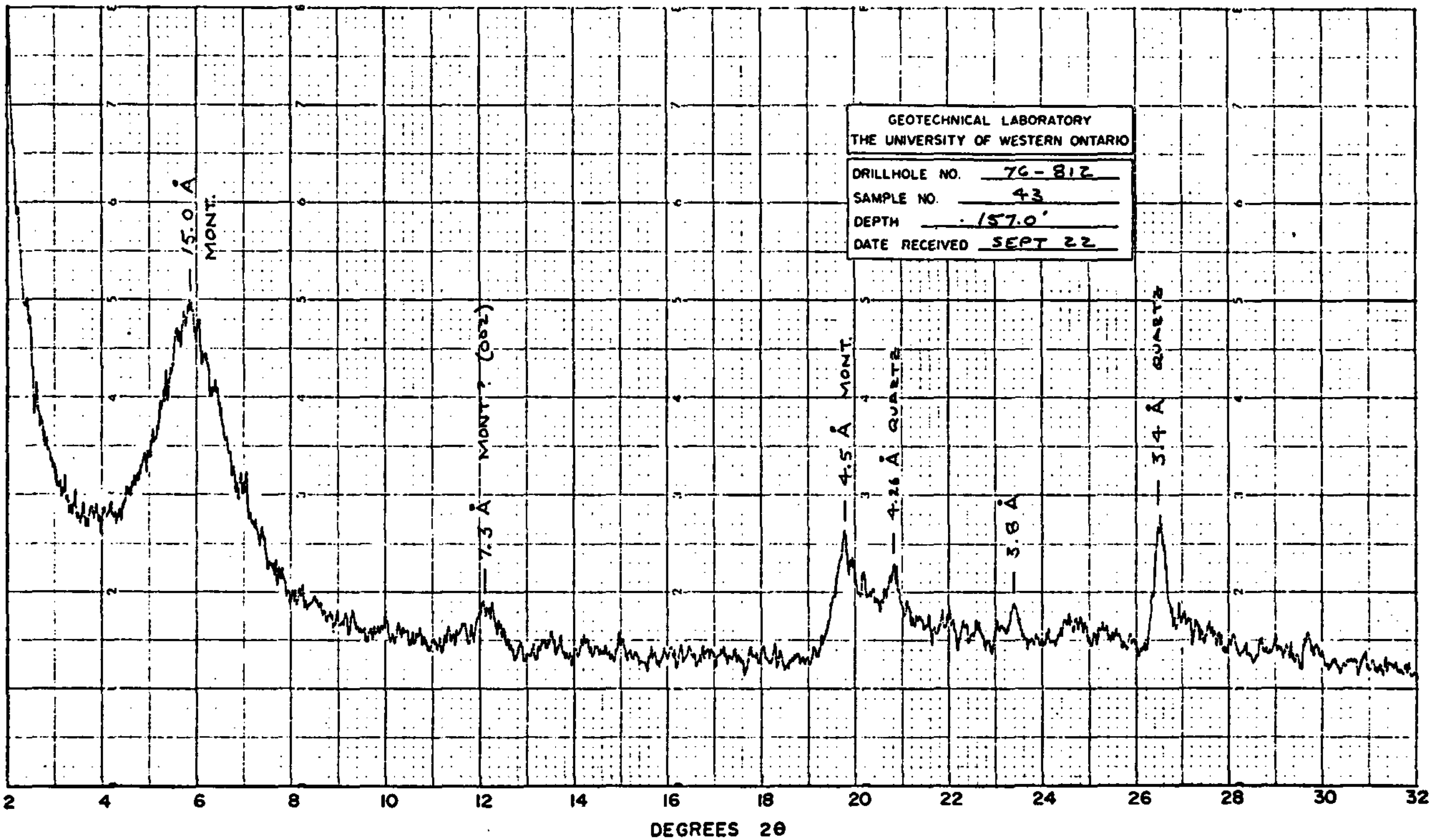

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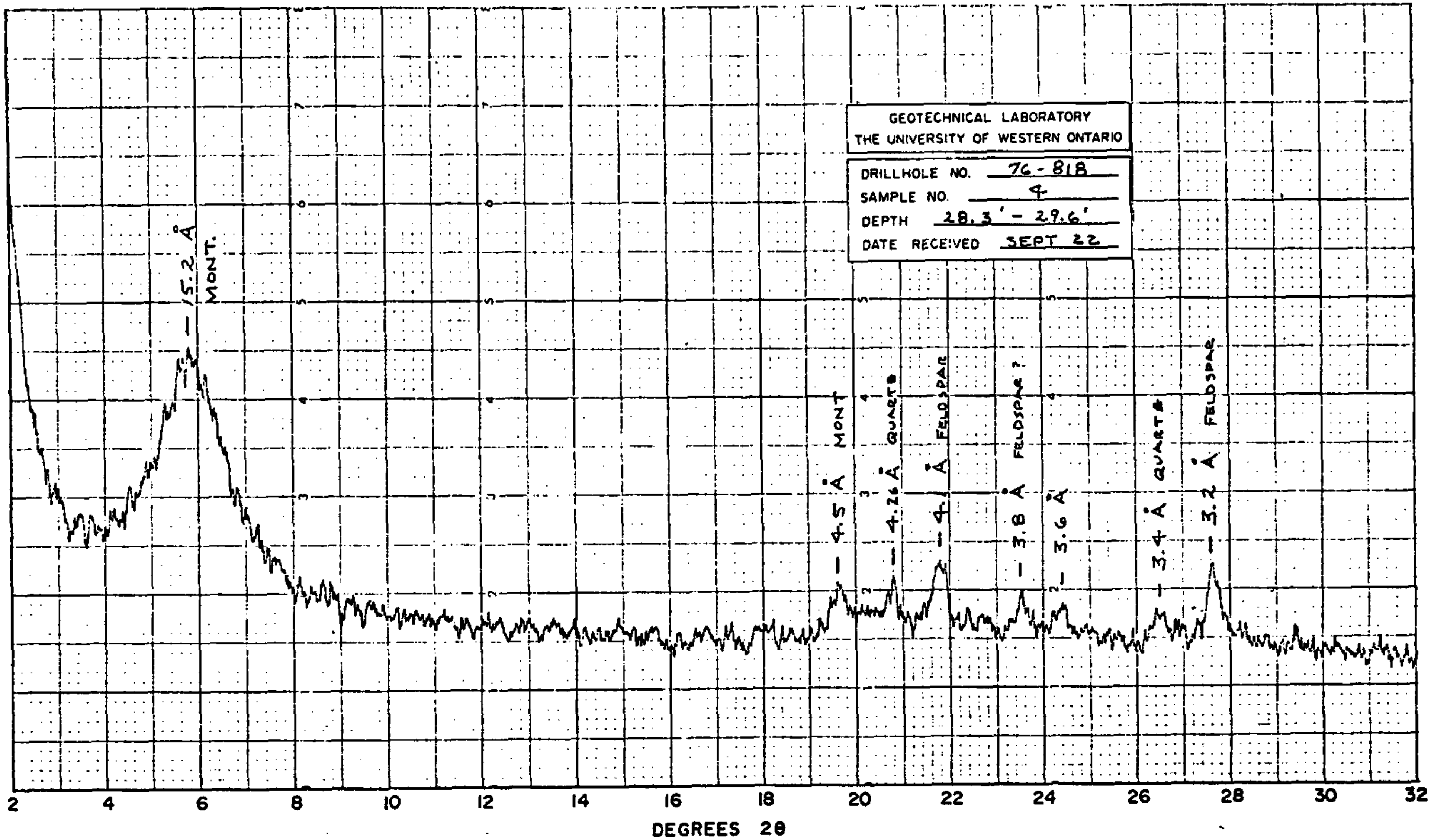

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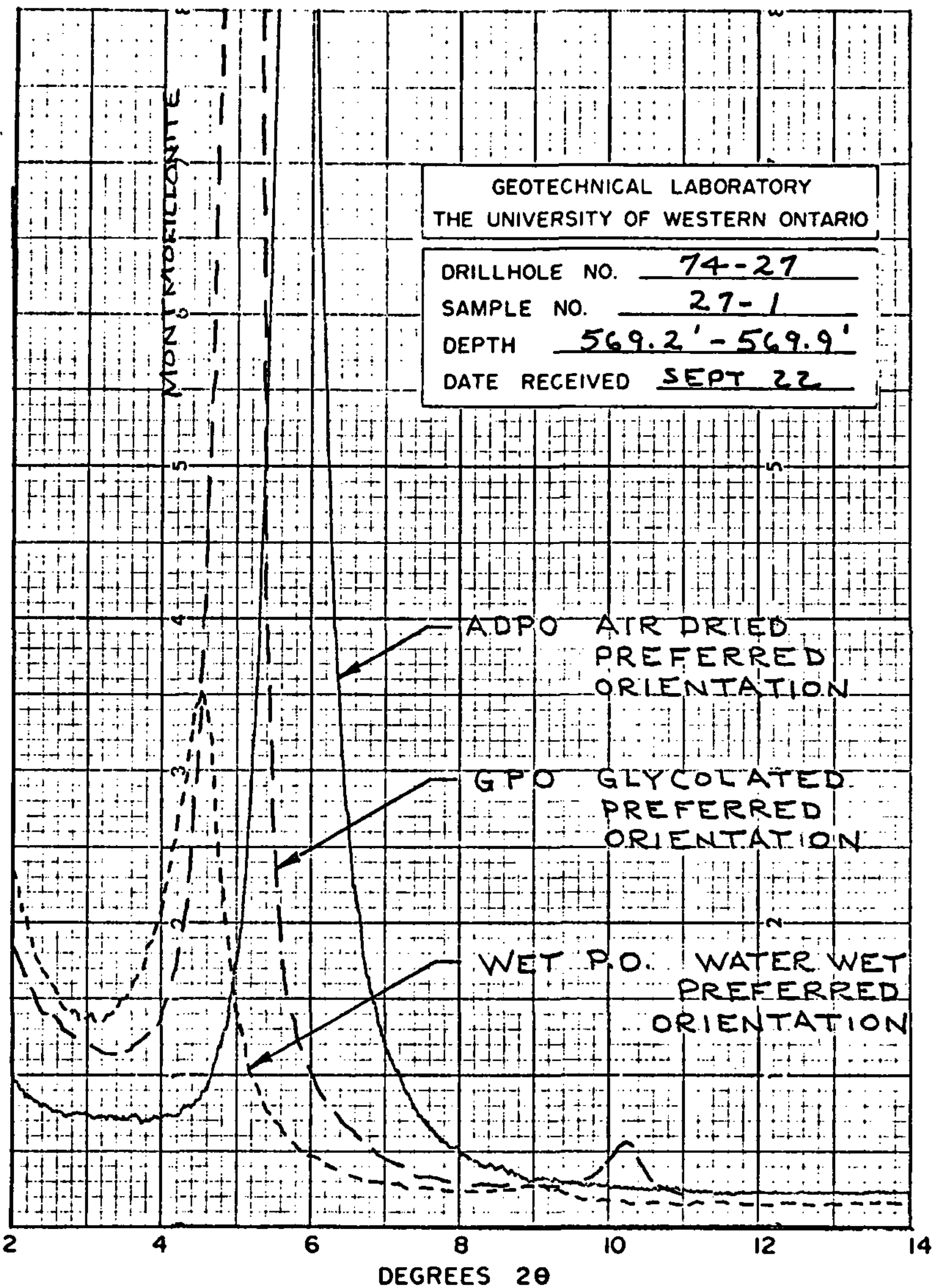

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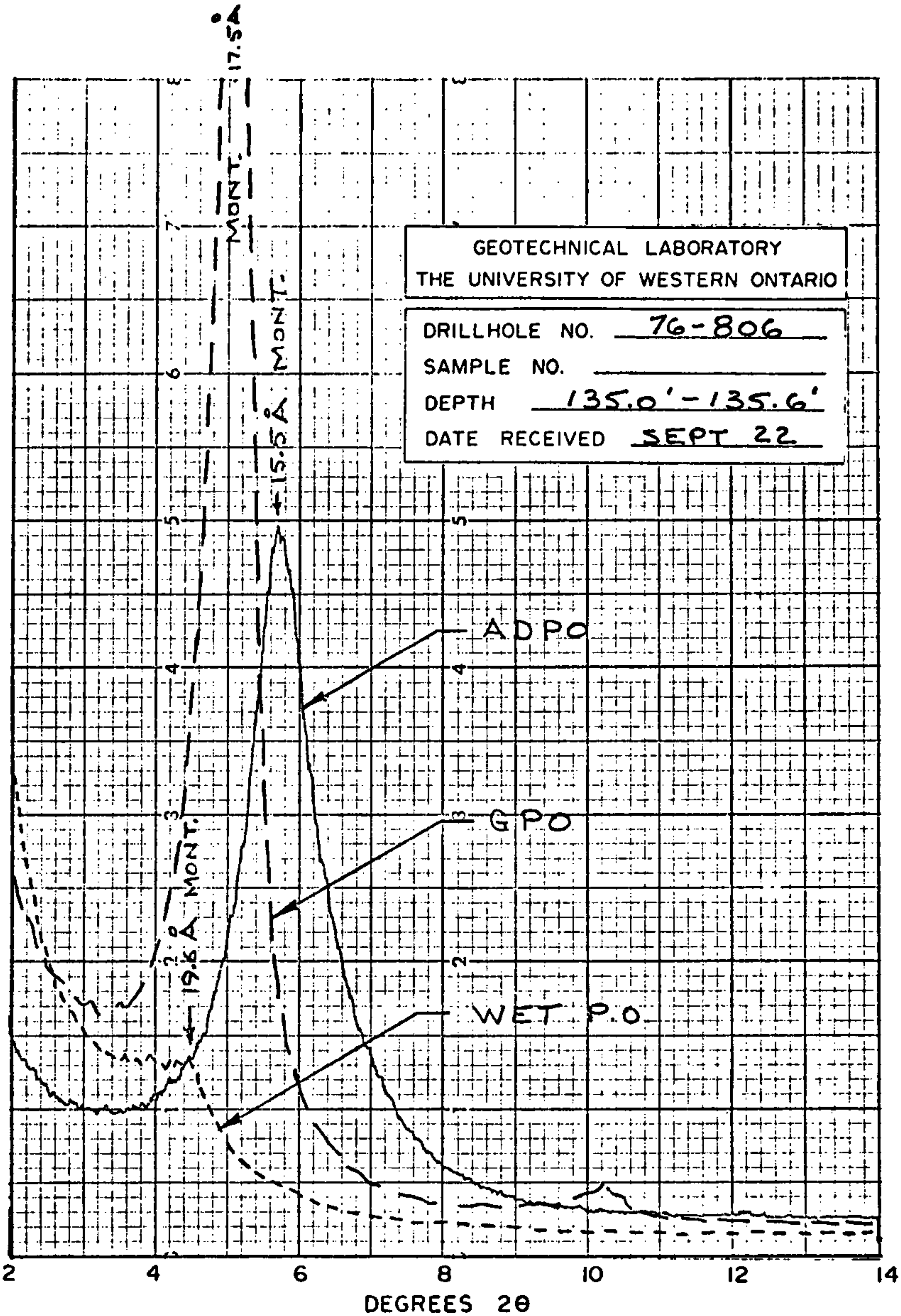

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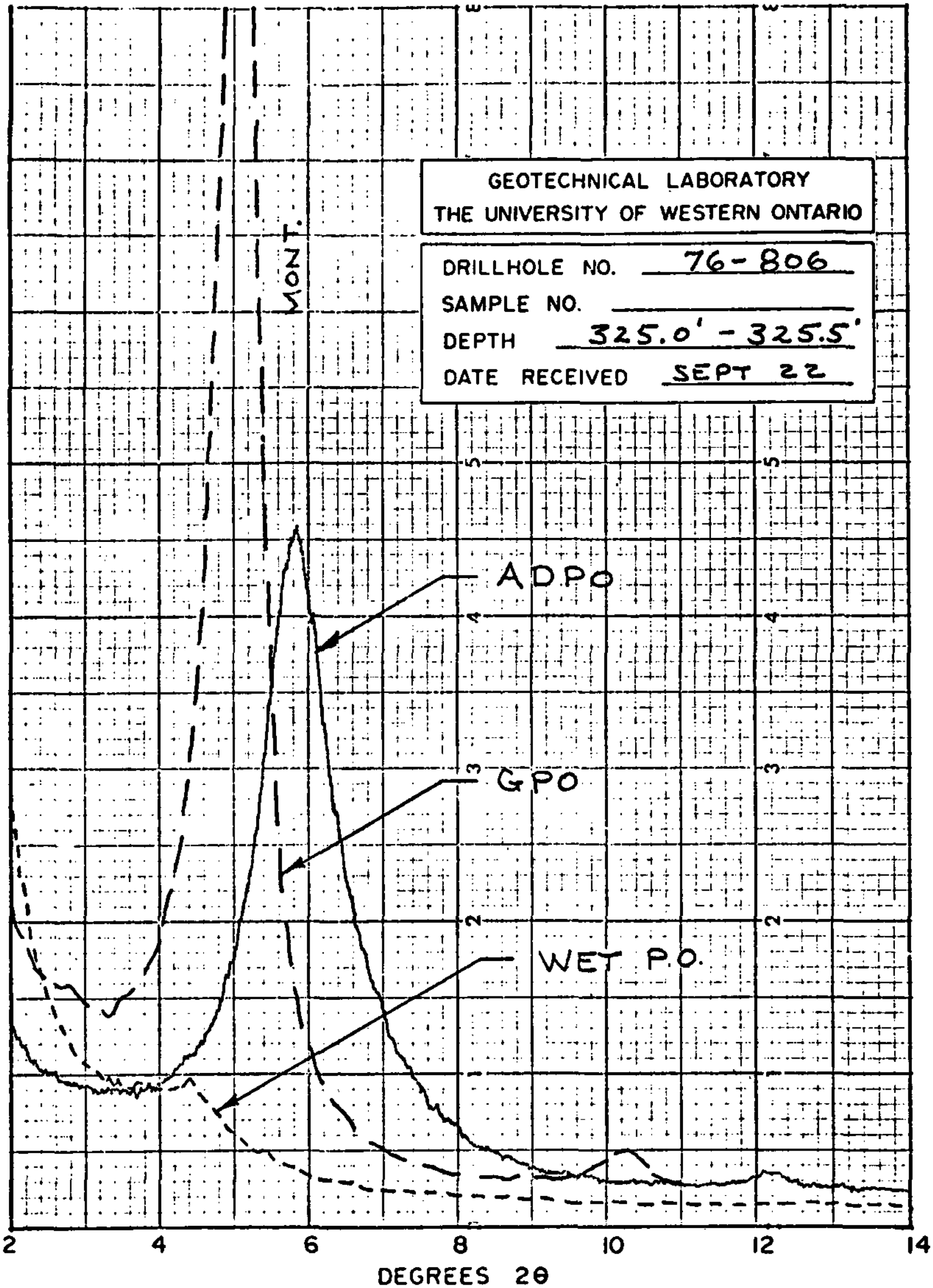

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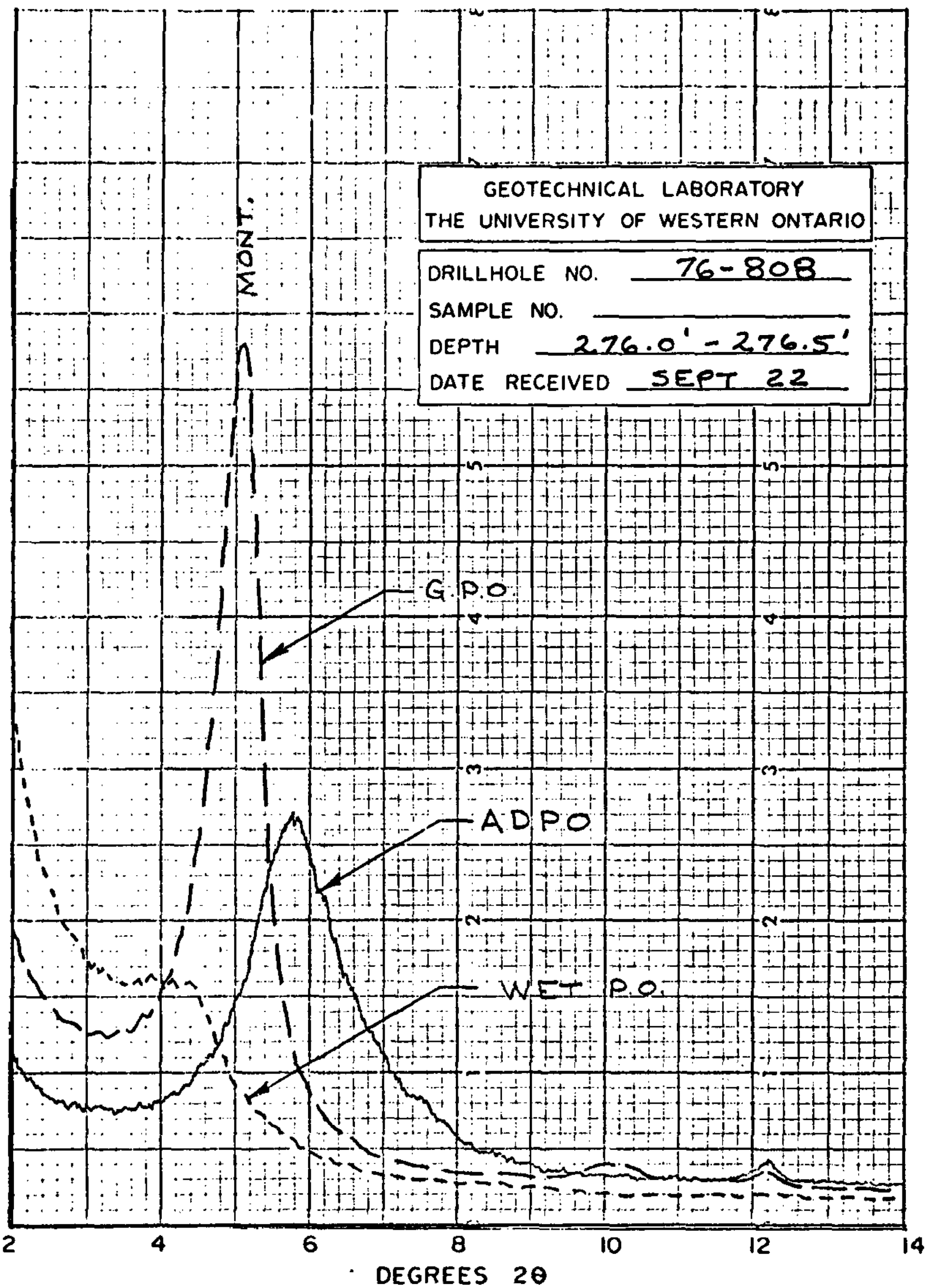

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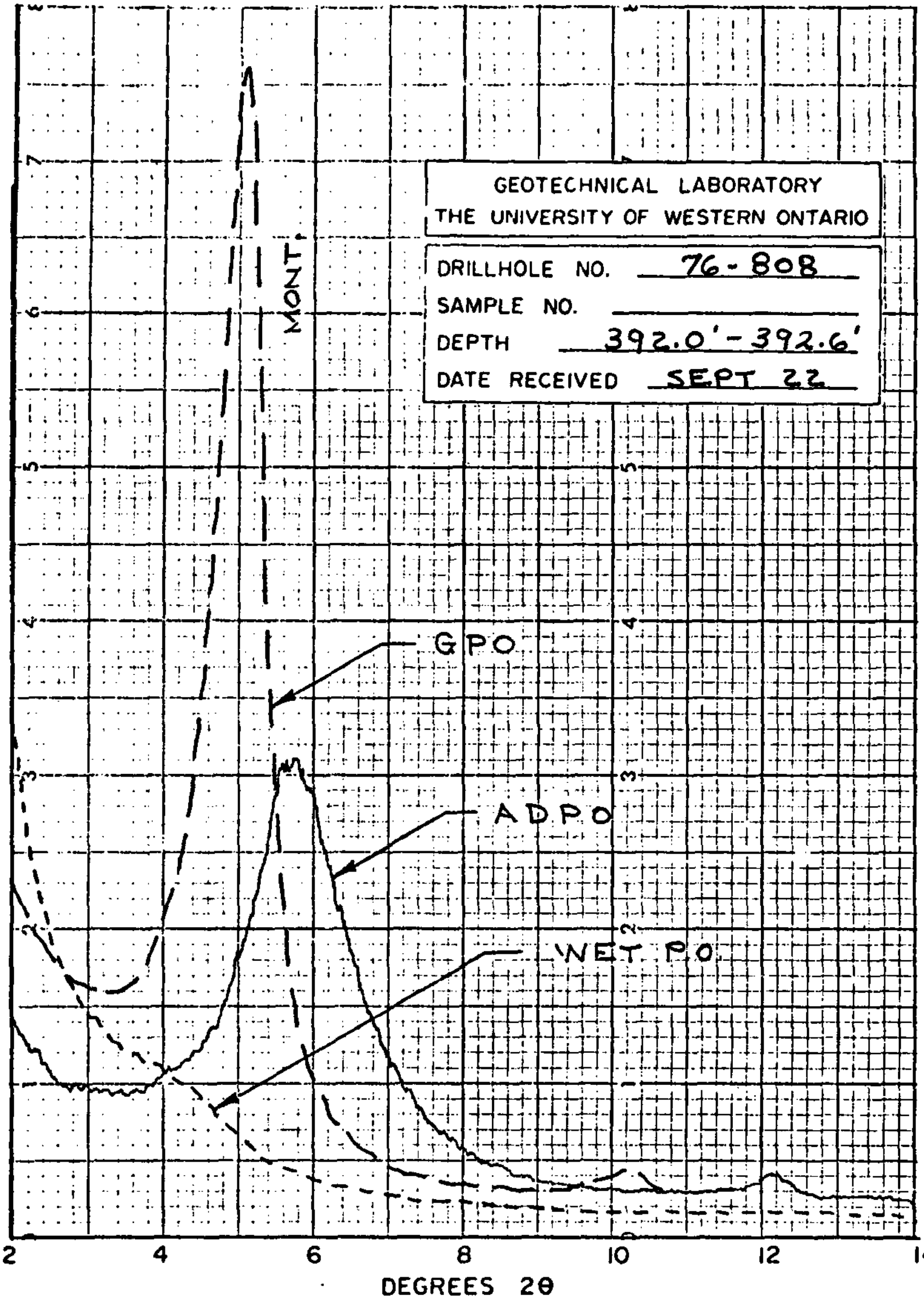

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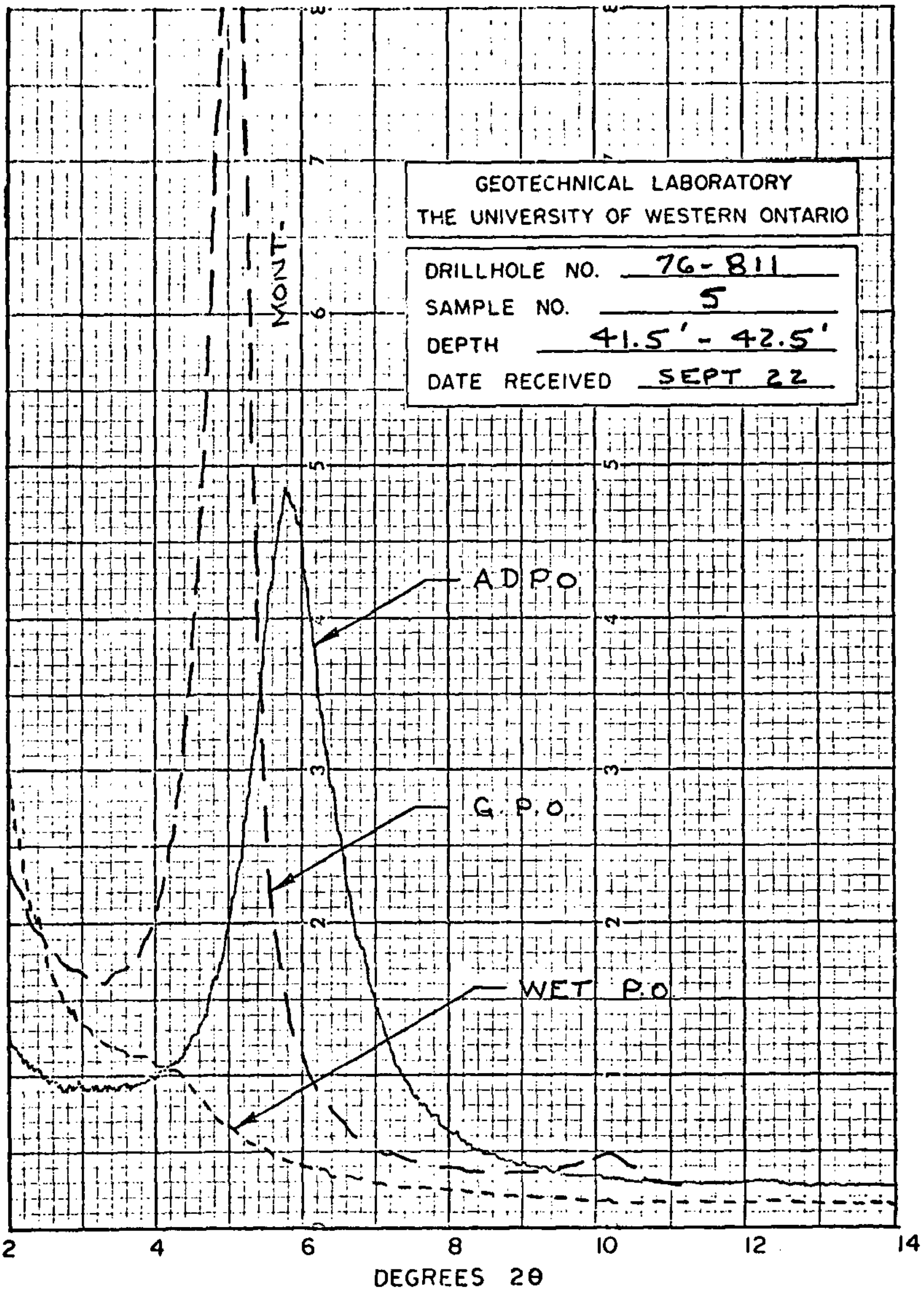

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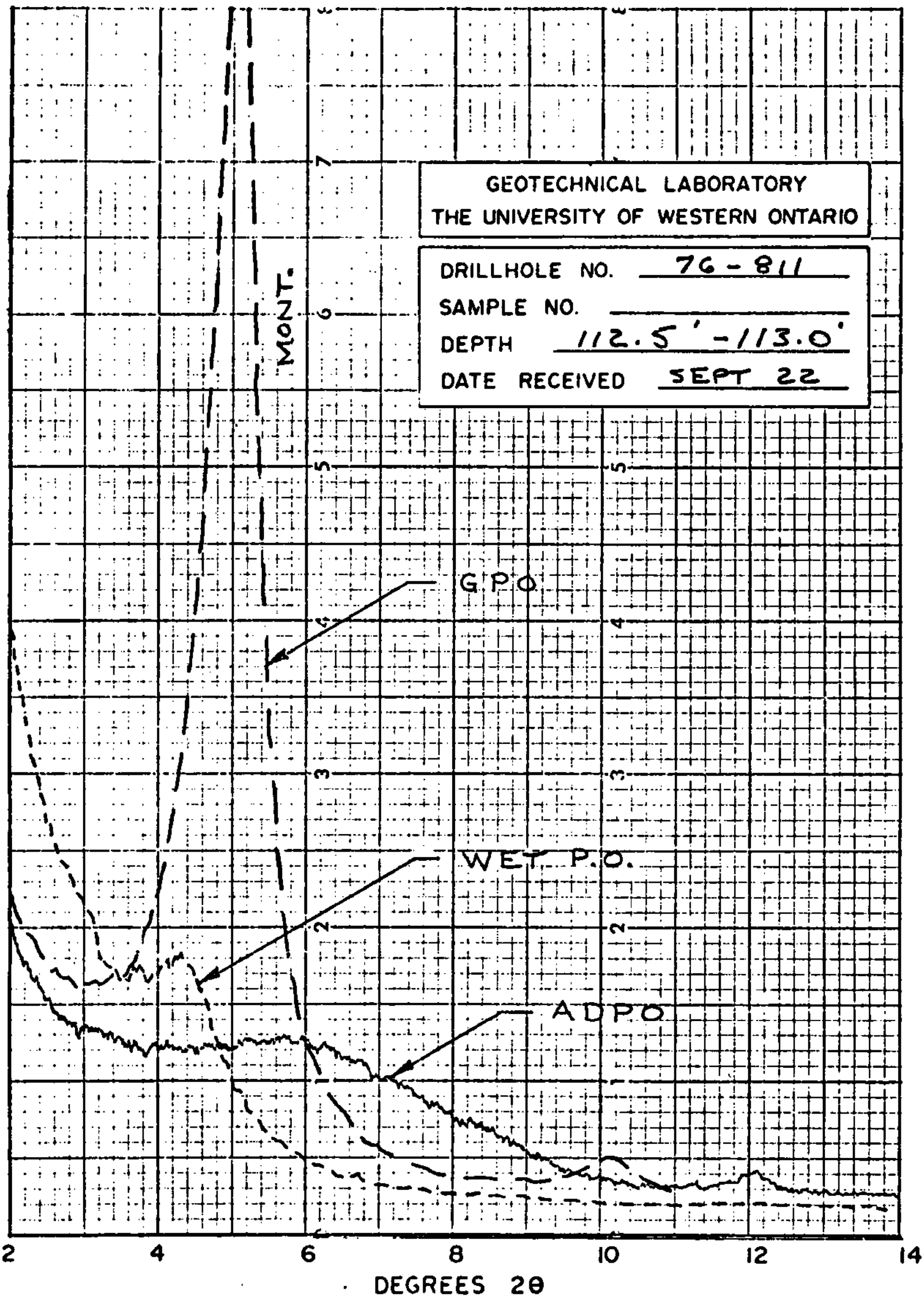

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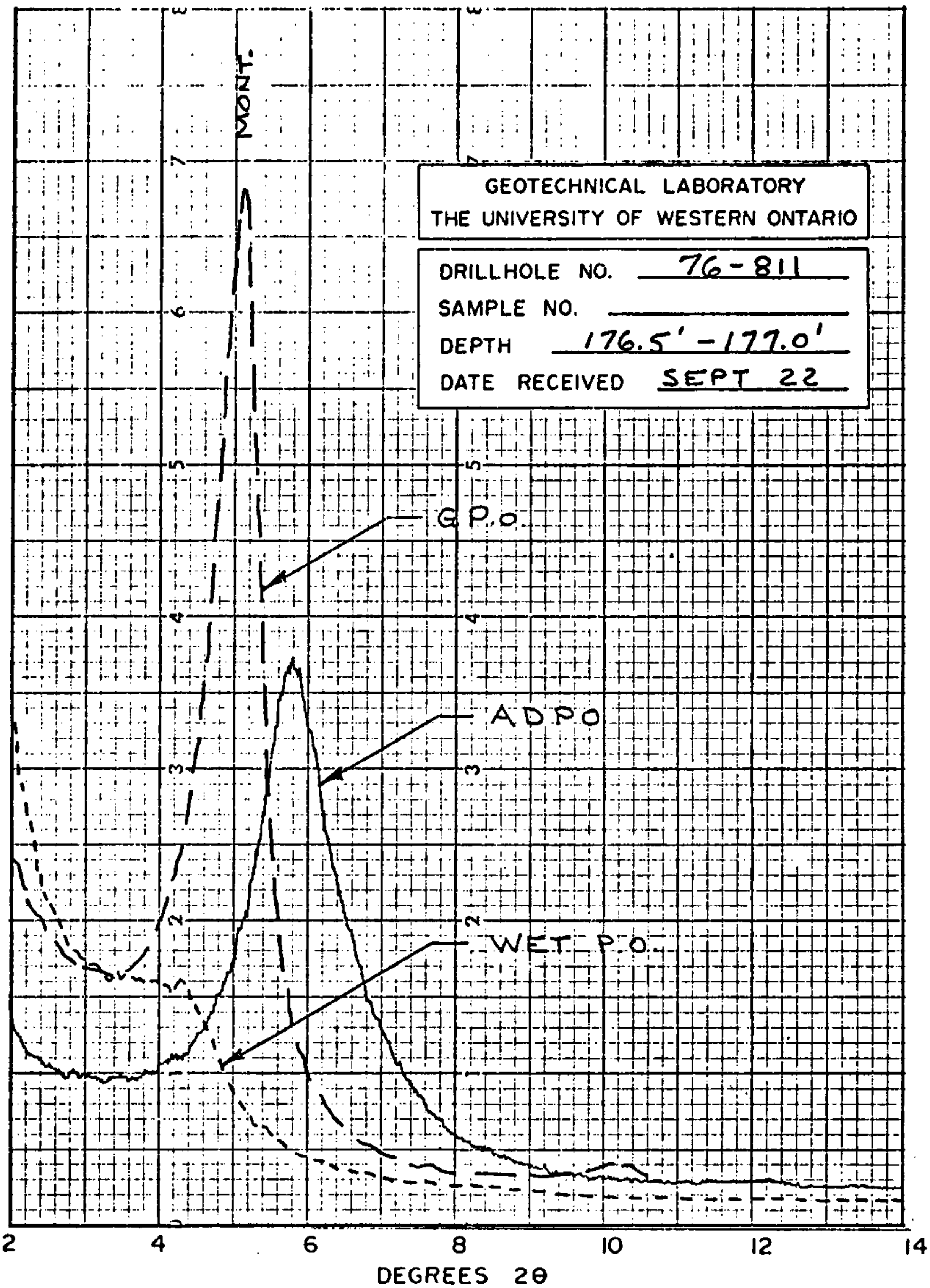

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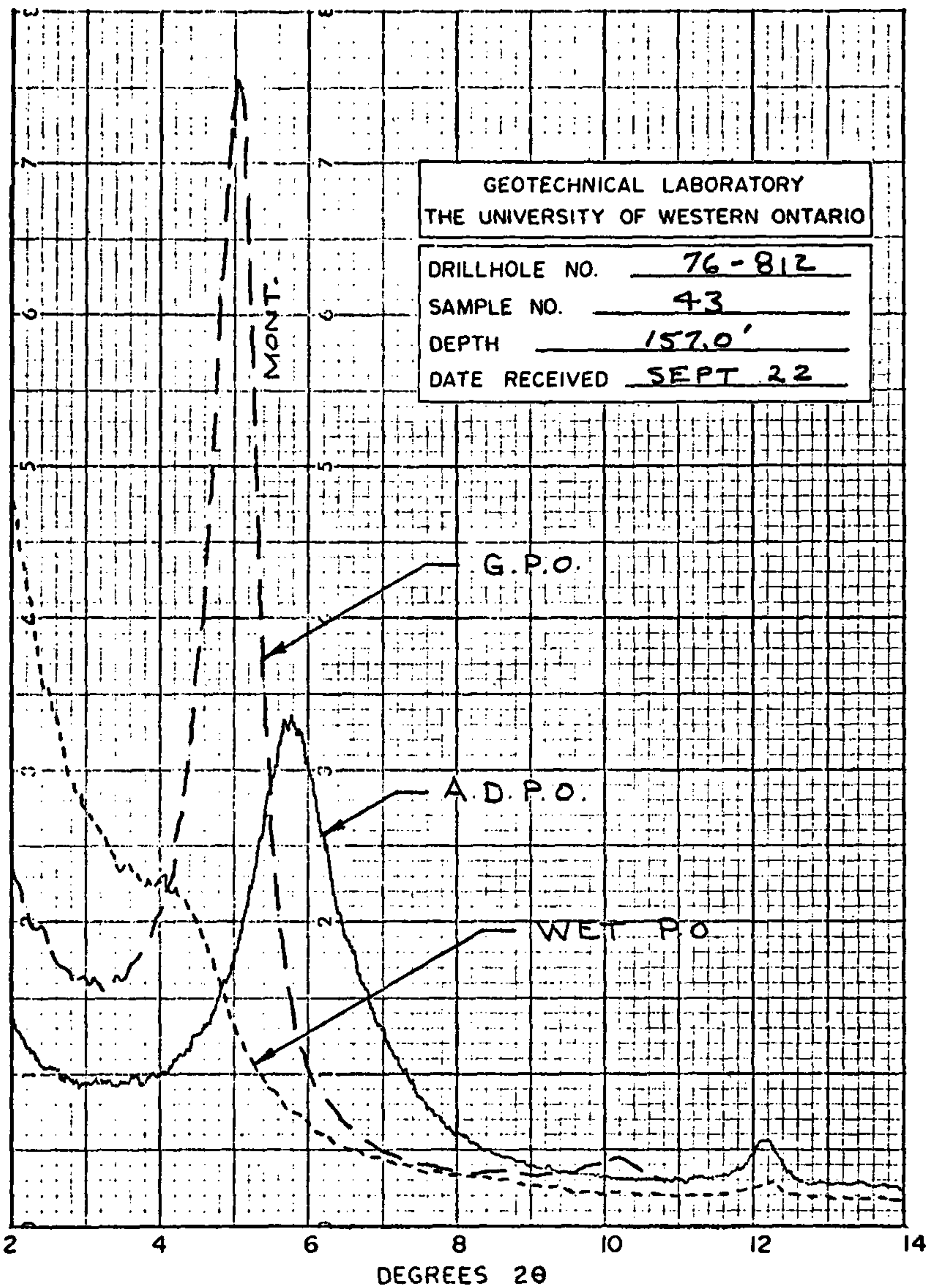

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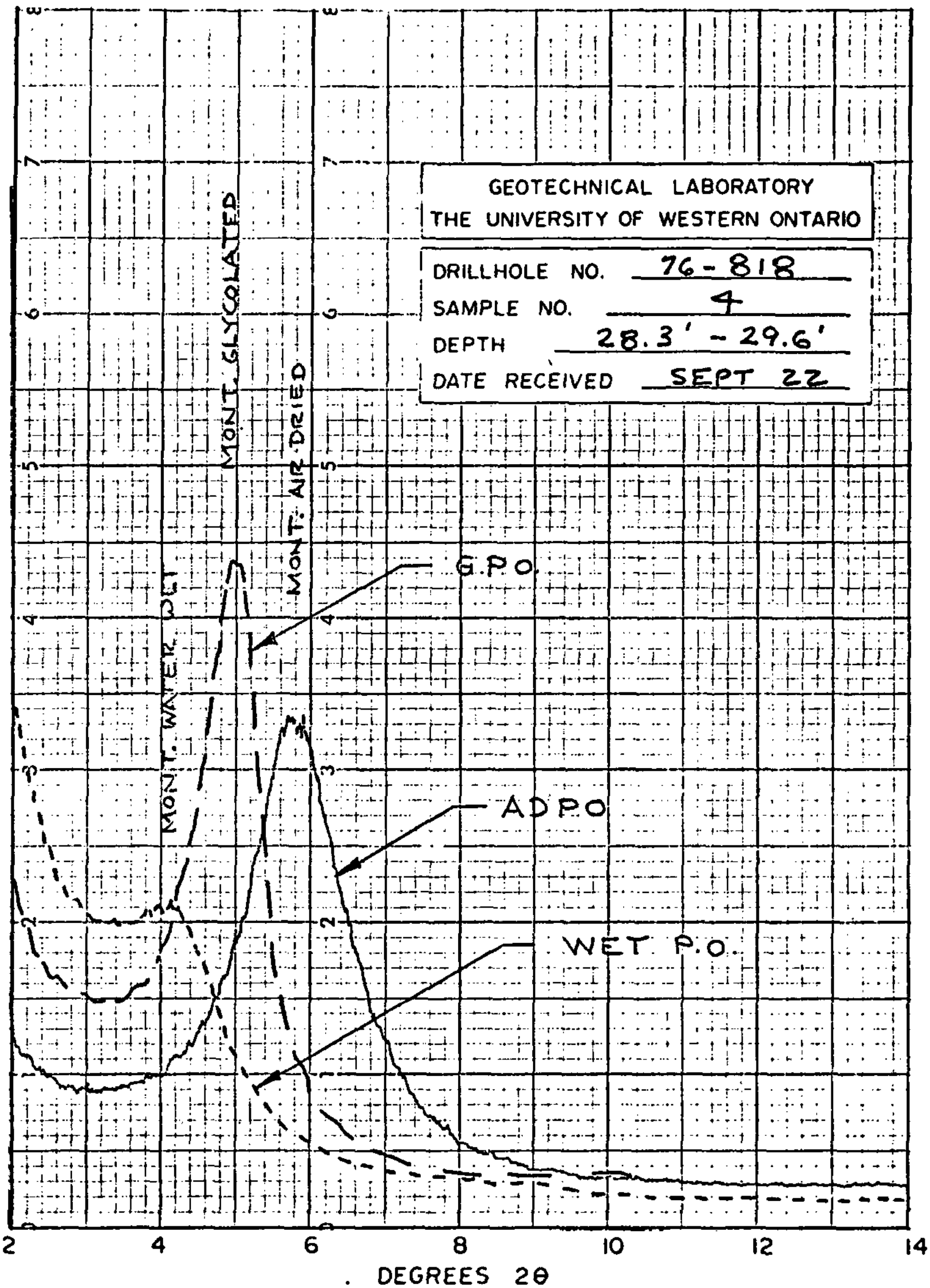

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REPORT

to

GOLDER BRAWNER & ASSOCIATES LTD.

VANCOUVER, BRITISH COLUMBIA

on

PRELIMINARY MINERALOGICAL

AND

PHYSICO-CHEMICAL ANALYSES

HAT CREEK PROJECT, BRITISH COLUMBIA

Robert M. Quigley

Faculty of Engineering Science
The University of Western Ontario
London, Ontario, Canada

November 26, 1976

TABLE OF CONTENTS

PRELIMINARY MINERALOGICAL AND PHYSICO-CHEMICAL ANALYSES, HAT CREEK PROJECT, B.C.

INTRODUCTION

This report presents a final summary of the results of mineralogical and chemical analyses carried out on 43 samples received from Golder Brawner Associates between June 24 and September 22, 1976.

X-ray powder patterns for whole soil samples, x-ray traces for oriented samples of < 2 μm fractions, and carbonate analyses on all samples were presented in a series of five letter reports between July 26 and October 8, 1976. Only a brief summary of these results is contained in this report.

Recent glycol retention analyses and pore fluid chemistry studies run as a final phase of the project are detailed herein.

PURPOSE AND SCOPE

The purpose of the present study has been to define the clay mineralogy of the sedimentary strata above, below and at the flanks of the coal measures at the Hat Creek Project, B.C. Of special interest were; 1) the relationship of the clay mineralogy to the probable engineering behaviour, and 2) the possible presence of a marker horizon.

A total of 43 samples were received from Golder Brawner & Associates Ltd. from a variety of locations defined stratigraphically on drawing V76345-3 (Golder Assoc.).

The scope of the testing has been limited to preliminary identification of the soil and rock components by x-ray diffraction and carbonate analyses. This has been supplemented by selected glycol retention analyses on 16 samples; 8 above the coal measures and 8 below. Salinity and cation analyses have been run on 8 samples; 4 above the coal measures and 4 below.

On the basis of the glycol retentions, a rough estimate can be made of the amount of montmorillonite present.

X-RAY DIFFRACTION SUMMARY

Powder Patterns

All powdered samples except those with more than about 35% carbonate yielded strong to very strong 15.2 Å montmorillonite peaks as shown in Figures 1 to 4 which contain typical powder patterns. The carbonate present appears to be an iron rich variety similar to siderite as identified on the x-ray traces. Other constituents in the samples included moderate to trace amounts of feldspar and quartz with an occasional suggestion of cristobalite.

Summaries of the soil constituents present in each sample as observed by x-ray powder diffraction are given in Tables I and II. For clarity, the carbonate contents by gasometric analysis are also given.

From an engineering point of view, the powder patterns clearly show montmorillonite to be the dominant mineral present in all samples except the indurated carbonates. Even in these samples, montmorillonite peaks were generally easily discernible on the powder patterns.

X-Ray Diffraction Traces of Oriented < 2 μm Fraction

Typical x-ray diffraction traces of oriented specimens of the < 2 μm fraction are given in Figures 5 to 8 inclusive. All traces are essentially similar showing strong 15.5 Å montmorillonite peaks in the air dried preferred orientation state and strong 17.0 Å peaks when glycolated. Some variation occurs in the traces for the water-wet samples, the intensity, breadth and position of the peaks varying from sample to sample. This reflects variable hydration of the clay mineral sheets and may be related in part to the quality of the distilled water used to disperse the samples as well as variable swelling characteristics of the clays.

From an engineering point of view, this tendency towards extra swell in distilled water suggests that the clays may exhibit unfavourable swelling and strength characteristics on exposure to leaching by fresh rain waters.

CHEMICAL TESTS

Chemical tests on the samples are summarized in Table III. The tests include carbonate analyses by Chittick gasometric methods, glycol retentions, pore fluid salinity and cation analyses.

Carbonate Analyses

Carbonate contents of the montmorillonite rich clays and clay-stones are generally of the order of 1 to 2%. Since the test procedure involves addition of HCℓ to a dried powdered sample, other gases than CO_2 from soil carbonates may occasionally be evolved. Test results of 1% carbonate, therefore, may reflect complete absence of carbonate in some of the samples.

The reaction time of the contained carbonates with HCℓ was delayed like dolomite, reflecting the lesser solubility of the siderite present in the rocks compared to calcite.

The x-ray traces clearly showed siderite to be the dominant carbonate. The presence of the siderite in the volcanic rich stratigraphic section would seem to reflect iron rich waters signifying volcanic activity synonymous with carbonate deposition.

Well indurated carbonate samples normally have siderite contents of about 30 to 35% with some samples containing as much as 68% carbonate. If the samples supplied to our laboratory are fully representative of the stratigraphic section, it is very apparent from Table III that the carbonate strata seem restricted to the section above the coal measures.

Glycol Retentions

The sixteen values of glycol retention are presented in Table III. Below the coal measures, values ranging from 129 to 264 were obtained on the $< 2\ \mu m$ fraction of six samples. The two high values of 243 and 264 mg/g are as high as is normally obtained on pure montmorillonite. Tests were run on two whole-soil samples (in brackets in Table III) and the results are very high (186 and 202 mg/g) indicating the great abundance of montmorillonite in the samples.

Above the coal measures, the glycol retentions varied from 136 to 265 mg/g on the $< 2\ \mu m$ fractions. These values are comparable in spread to those obtained on the samples from below the coal measures.

Again, the four values above 200 mg/g are indicative of a clay fraction consisting of pure montmorillonite.

Salinity and Cation Analyses

Sample preparation for pore fluid analysis involved a single addition of distilled water to air dried soil in the ratio of 5:1 by weight. The salinities were measured by conductivity meter and are referred to $NaC\ell$ standard. All values were calculated assuming an in situ moisture content of 35% which is close to the actual average value.

Extreme difficulty was experienced in obtaining a clear liquid since the montmorillonite tended to form a very stable gel, even in dilute suspension. Eventually, all samples were split into small fractions and successfully clarified by high speed centrifugation.

The pore fluid cation analyses were run on the clear, slightly brown supernatant using a Pye Unicam atomic absorption spectrophotometer. The results only represent a guide to the pore fluid composition, since pore fluid extraction by high pressure squeezing would be required to obtain more precise values. The values of the salinity and cation measurements are presented in Table III.

The salinity values on the clay-stones tested are close to 4 g/ℓ except for sample 74-28-1 (480 ft) which has a somewhat higher value of 6.5 g/ℓ. The lowest salinity value of 1.9 g/ℓ was obtained on sample 803-28 (135 ft) which is understood to be a glacio-lacustrine sediment. The lower salinity is, therefore, not surprising.

The cation analyses showed Na^+ (sodium) to be the dominant constituent of the pore fluid with values ranging from 1.15 to 2.13 g/ℓ for the montmorillonite clay-stones. Magnesium was the next most abundant cation, ranging from 0.03 to 0.78 g/ℓ. Iron was present in three brown coloured liquid extracts in amounts of 0.12 to 0.74 g/ℓ and absent in the rest of the extracts. Calcium was a negligible component of the pore fluids as extracted by the distilled water wash.

Chloride Anion Measurements

Chloride anion measurements were carried out on four selected extracts and yielded concentrations varying from 0.03 to 1.93 g/ℓ as shown in Table III. Although the data is slim, it is speculated that high sodium values correlate with high chlorinity values in the Hat Creek deposits.

pH Measurements

The soil samples prepared for salinity analyses were also checked for pH yielding the results in Table III. The measured values range from 8.6 to 9.3 indicating a significantly alkaline environment.

DISCUSSION

The x-ray powder diffraction and carbonate data indicate that the geologic materials within the stratigraphic sequence at Hat Creek consist of:

1) Essentially pure montmorillonite with trace amounts of quartz and feldspar
2) Montmorillonite with moderate amounts of quartz and feldspar

3) Montmorillonite with moderate amounts of siderite

4) Carbonates (siderite) with moderate amounts of montmorillonite.

It appears significant that in Table I, all of the siderite rich samples occur above the coal measures.

The x-ray traces for the oriented specimens feature very strong (001) montmorillonite peaks with little or no evidence of either 10 Å illite or 7 Å kaolinite and chlorite. The very high glycol retentions of 129 to 264 reflect the abundance of montmorillonite within all < 2 μm fractions tested, including the indurated carbonates.

If pure montmorillonite is assigned its usual glycol retention of 250 mg/g, then the two whole soil samples tested (186 and 202 mg/g) contain montmorillonite contents of about 75 and 81% respectively.

The cations present in the pore fluid extracts consisted dominantly of sodium (1.2 to 2.1 g/ℓ) with a somewhat lower value of 0.71 in the glacio-lacustrine sample 803-28 (135 ft). Magnesium was the next most abundant species with 0.03 to 0.06 g/ℓ in the pore fluid above the coal measures and 0.14 to 0.78 g/ℓ in the pore fluid of samples from below the coal measures. Calcium was essentially absent from the extracts, however, HCℓ treatment of a couple of samples suggested that some Ca^{++} may be adsorbed on the clays. Iron was detected in only the three most strongly coloured extracts.

Since magnesium (Mg^{++}) is a divalent cation it preferentially adsorbs onto the clay minerals in comparison to Na^{+}, a univalent cation. Most of the cations adsorbed on the soil montmorillonites will, therefore, probably be Mg^{++}.

The total cation composition of the pore fluid extracts compares reasonably favourably with the measured salinity values. For example, the pore fluid extract from sample #74-28-1 (480 ft) has the following measured chemical constituents:

<u>Sa #74-28-1 (480')</u>

Salinity	=	6.46 g/ℓ
Sodium	=	2.07 g/ℓ
Magnesium	=	0.03 g/ℓ
Calcium	=	0.04 g/ℓ
Σ cations	=	2.14 g/ℓ
Chloride	=	1.93 g/ℓ
Σ cations + chloride	=	4.07 g/ℓ

Other anionic constituents such as bicarbonates and sulphates probably comprise the remainder of the soluble salts. Indeed, the very high pH values suggest the presence of soluble sulphates and it is recommended that some sulphate analyses be carried out during the next phase of the investigations.

Sodium rich montmorillonites have much higher liquid limits and activities than magnesium and calcium rich montmorillonites. They also have correspondingly lower residual friction angles. The montmorillonites above the coal measures contain significantly less divalent cations and more Na^{++} cations in the pore fluid extracts, suggesting that they may be consistently more active and difficult to manage when exposed to atmospheric weathering than those below the coal measures.

Should strata be encountered that have significantly higher activities than the norm for surrounding strata, it is recommended that they receive special chemical testing to establish the pore fluid chemistry and adsorbed cation regime.

TABLE I. COMPOSITION FROM X-RAY POWDER PATTERNS; BOREHOLE SAMPLES

A = Abund., Mo = Mod., Mi = Minor, T = Trace

SAMPLE			CARBONATE (Whole soil) (%)	CONSTITUENTS FROM X-RAY POWDER ANALYSES
Drill Hole	Number	Depth (ft)		
Above coal measures:				
803	28	135	1.7	Mont-A, Feldspar-A, Quartz-A
"	29	317	32.4	Mont-A, Siderite-A, Quartz-T
"	-	595	17.1	Mont-A, Felds-A, Siderite-A, Qtz-Mo (Fig.3)
815	7	431	34.5	Mont-A, Siderite-A, Felds-T
"	9	448	51.2	Mont-A, Siderite-A
"	12	482.5	3.5	Mont-A, Feldspar-Mi
"	14	506	7.5	Mont-A, Siderite-Mi, Qtz-T
"	18	542	34.3	Mont-?, Siderite-A, Qtz-T
"	20	562	9.3	Mont-A, Siderite-Mi, Qtz-Mi, Felds-Mi
"	22	583	67.6	Mont-?, Siderite-A, Qtz-T
"	29	669.5	35.5	Mont-?, Siderite-A, Qtz-T
816	19	473	30.7	Mont-?, Siderite-A, Qtz-T
74-27	1	569.5	60.4	Mont-?, Siderite-A
74-28	1	480	2.0	Mont-A, Felds-Mi, Qtz-Mi
"	2	644	6.4	Mont-A, Qtz-Mi, Siderite-Mi, Cristobalite?-Mi
"	3	738	7.5	Mont-A, Siderite-Mi, Qtz-T
"	4	763	31.6	Mont-A, Siderite-A, Qtz-Mi, Felds-Mi
"	5	767.5	26.5	Mont-A, Siderite-A, Qtz-Mo, Felds-Mi
"	6	179.5	44.3	Mont-?, Siderite-A, Qtz-T
"	7	451	12.9	Mont-A, Siderite-Mo
"	8	537	2.7	Mont-A, Felds-Mo, Qtz-Mi
"	9	588	1.5	Mont-A, Felds-Mi, Qtz-T
Below coal measures:				
804	1A	51	1.7	Mont-A, Felds-A, Qtz-Mi
805	16 Green Black	62	5.3 1.1	Mont-A, Felds-Mi, Qtz-Mi
806	7	18	1.3	Mont-A, Felds-Mo, Qtz-Mo
"	-	135	2.5	Mont-A, Felds-Mo, Qtz-Mi
"	-	325	2.1	Mont-A, Felds-Mo, Qtz-Mi
807	12	23	2.4	Mont-A, Felds-Mi, Qtz-Mi
"	14	159	1.7	Mont-A, Qtz-Mo
808	40	12	3.0	Mont-A, Felds-Mo, Qtz-T
"	10	32	1.7	Mont-A, Felds-Mo, Qtz-Mi
"	-	276	2.7	Mont-A, Felds-Mi
"	-	392	1.5	Mont-A, Felds-Mi, Qtz-Mi
809	2	15	2.6	Mont-A, Felds-Mo, Qtz-Mi, Cristob-Mi?
"	4	33	2.7	Mont-A, Felds-Mo
811	5	42	1.3	Mont-A, Felds-Mo, Qtz-Mi
"	-	113	4.5	Mont-A, Qtz-Mo, Felds-Mi, Siderite-Mi
"	-	177	2.5	Mont-A, Qtz-Mi, Felds-Mi
812	43	157	2.2	Mont-A, Qtz-Mo
818	4	29	2.4	Mont-A, Felds-Mo, Qtz-Mi

TABLE II. COMPOSITION; MUD BOIL AND SLIDE HEADWALL SAMPLES

SAMPLE		CARBONATES (Whole soil) (%)	CONSTITUENTS FROM X-RAY POWDER ANALYSES
MUD BOIL		4.0	Mont-abund. Quartz-mod. Felds-abund. Dolomite-minor
SLIDE HEADWALL	T1	2.8	Mont-abund., Quartz-abund., Feldspar-moderate
"	T2	3.8	Mont-abund., Quartz-abund., Feldspar-abund.
"	T3	4.2	Mont-abund., Feldspar-abund., Quartz-trace

TABLE III. CHEMICAL TEST RESULTS; BOREHOLE SAMPLES

SAMPLE			CARBONATE (Whole soil)	GLYCOL RETENTION on < 2 µm	SALINITY	Na	Ca	Mg	Fe	Cℓ	pH
Drill Hole	Number	Depth (ft)	%	mg/g	g/ℓ	g/ℓ	g/ℓ	g/ℓ	g/ℓ	g/ℓ	
Above coal measures:											
803	28	135	1.7	207	1.9	0.71	0.02	0.04	-	-	8.7
"	29	317	32.4	142							
"	-	595	17.1	213							
815	7	431	34.5								
"	9	448	51.2								
"	12	482.5	3.5	233							
"	14	506	7.5								
"	18	542	34.3								
"	20	562	9.3	136	3.4	1.15	0	0.06	-	-	8.6
"	22	583	67.6								
"	29	669.5	35.5								
816	19	473	30.7								
74-27	1	569.5	60.4								
74-28	1	480	2.0		6.46	2.07	0.04	0.03	0	1.93	8.7
"	2	644	6.4	167							
"	3	738	7.5	265							
"	4	763	31.6								
"	5	767.5	26.5								
"	6	179.5	44.3								
"	7	451	12.9								
"	8	537	2.7	190	3.9	1.24	0	0.05	0	0.96	8.6
"	9	588	1.5								
Below coal measures:											
804	1A	51	1.7								
805	16 Green Black	62	5.3 1.1								
806	7	18	1.3								
"	-	135	2.5			1.96	-	0.78	-	? 0.03	-
"	-	325	2.1								
807	12	23	2.4								
"	14	159	1.7								
808	40	12	3.0								
"	10	32	1.7								
"	-	276	2.7	185	4.6	2.13	0	0.49	0.74	0.24	9.3
"	-	392	1.5	131							
809	2	15	2.6								
"	4	33	2.7								
811	5	42	1.3	(186) 180	-						
"	-	113	4.5	129							
"	-	177	2.5	(202) 243	4.2	2.10	0	0.63	0.62	-	9.3
812	43	157	2.2								
818	4	29	2.4	264	3.7	1.59	0	0.14	0.12	-	9.1

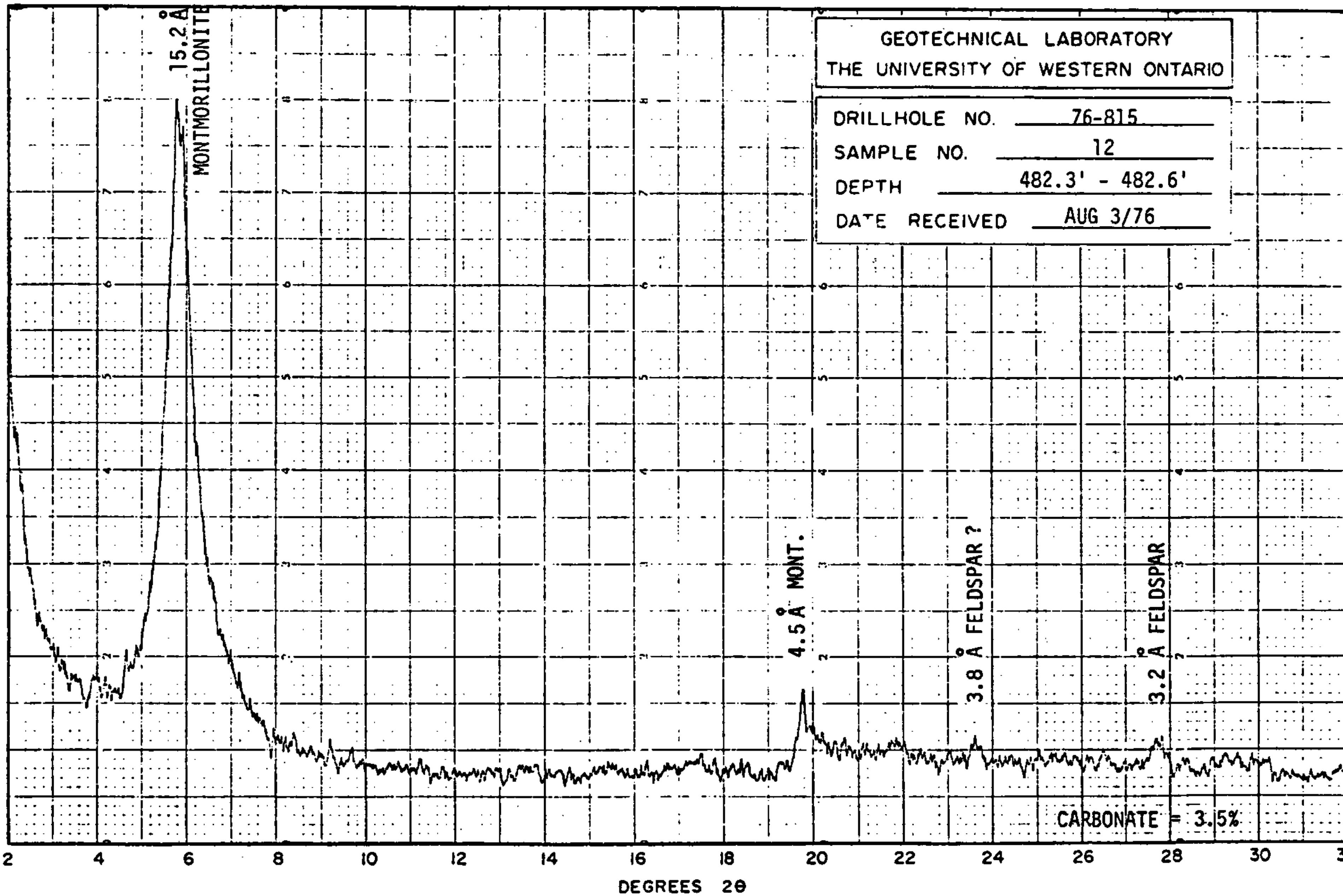


FIG. 1. X-RAY DIFFRACTION TRACE OF WHOLE SOIL POWDER FROM HAT CREEK.

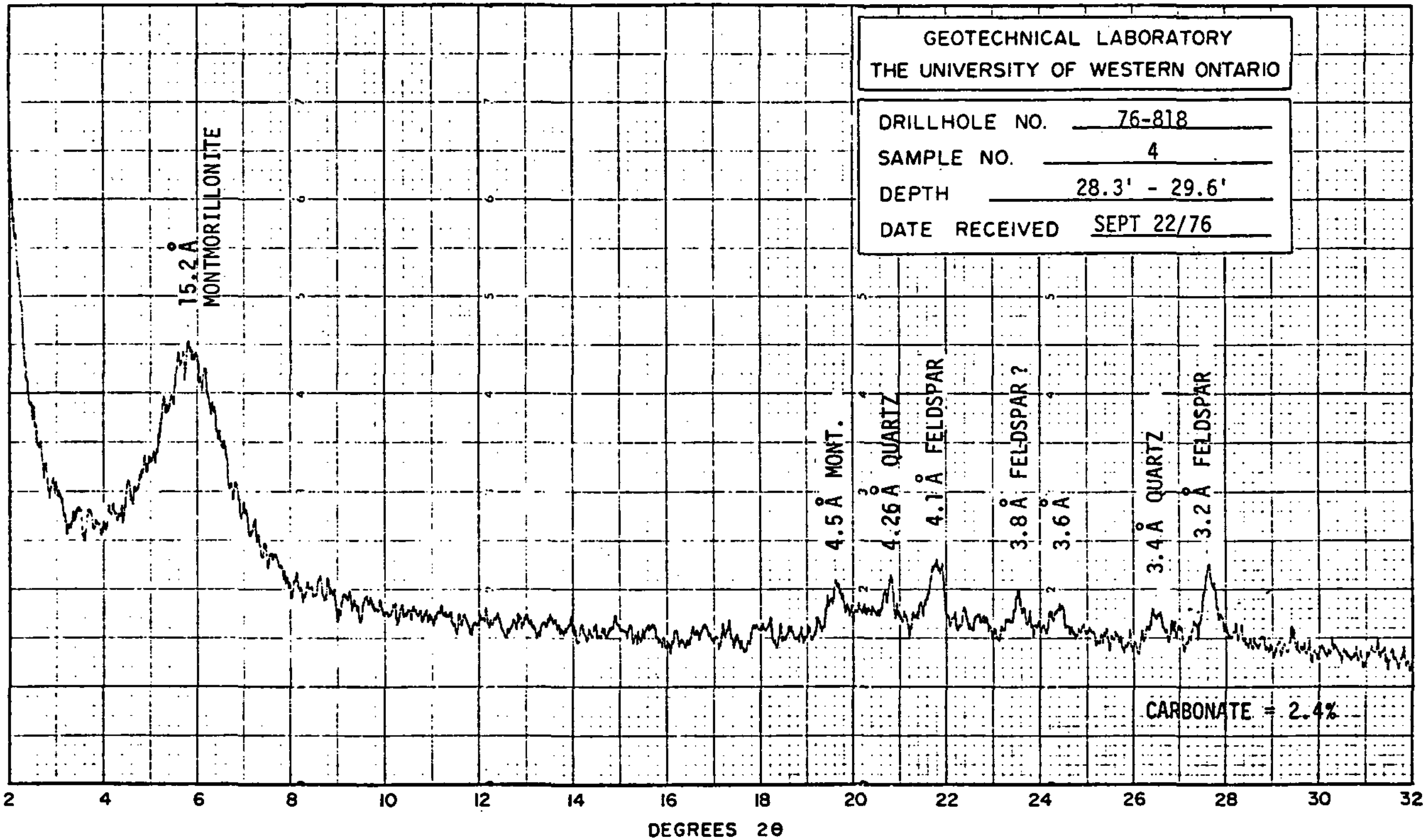


FIG. 2. X-RAY DIFFRACTION TRACE OF WHOLE SOIL POWDER FROM HAT CREEK.

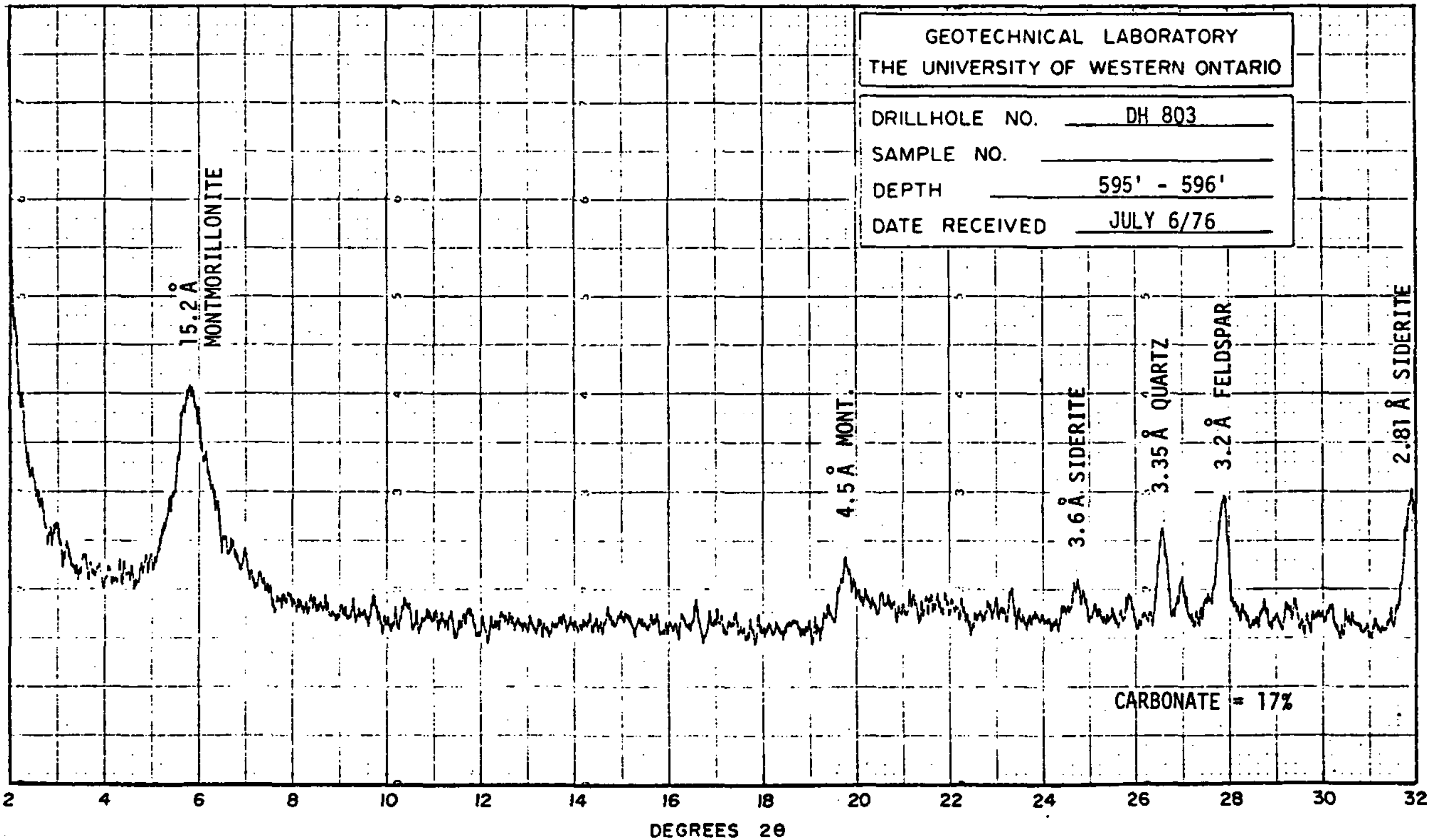


FIG. 3. X-RAY DIFFRACTION TRACE OF WHOLE SOIL POWDER FROM HAT CREEK.

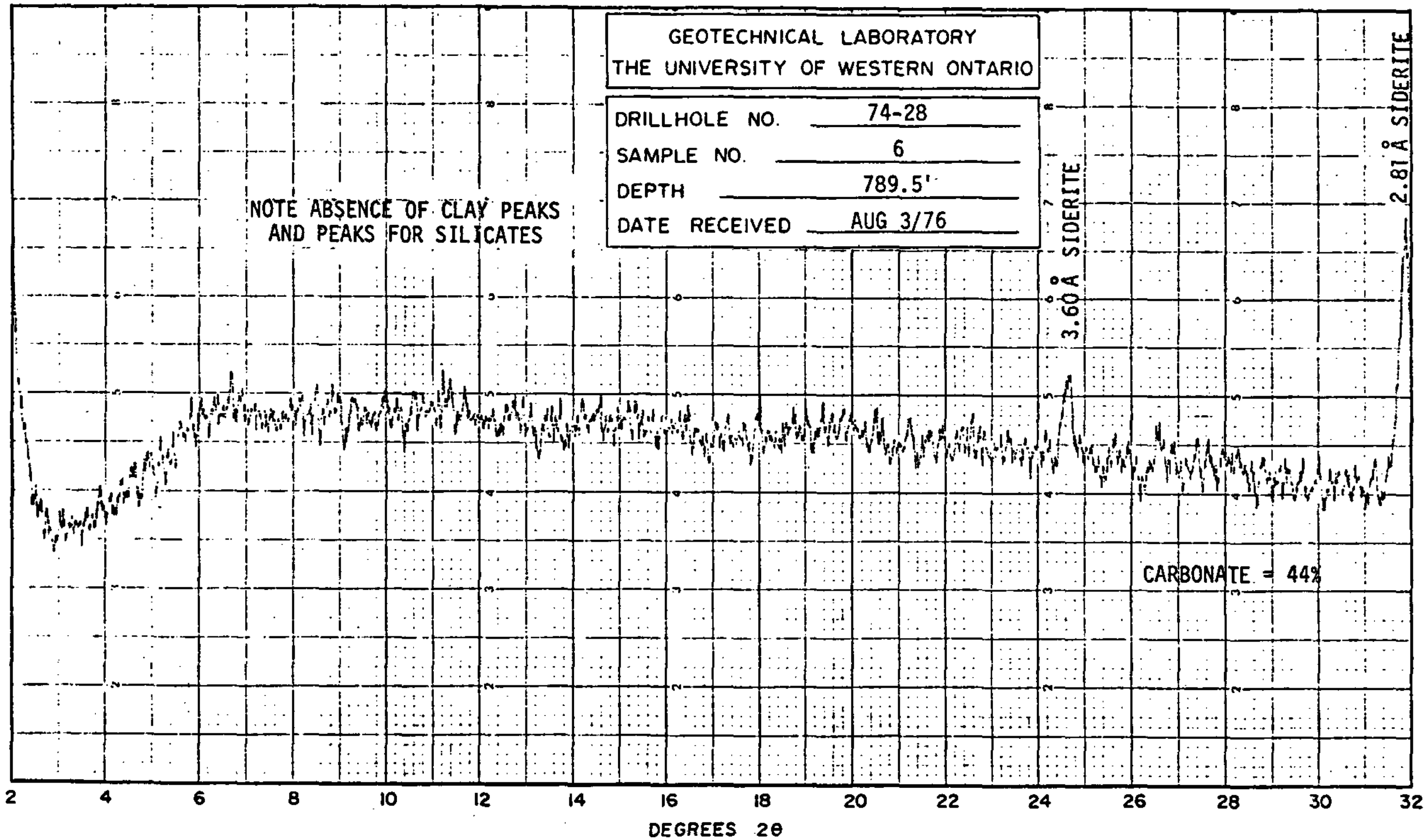
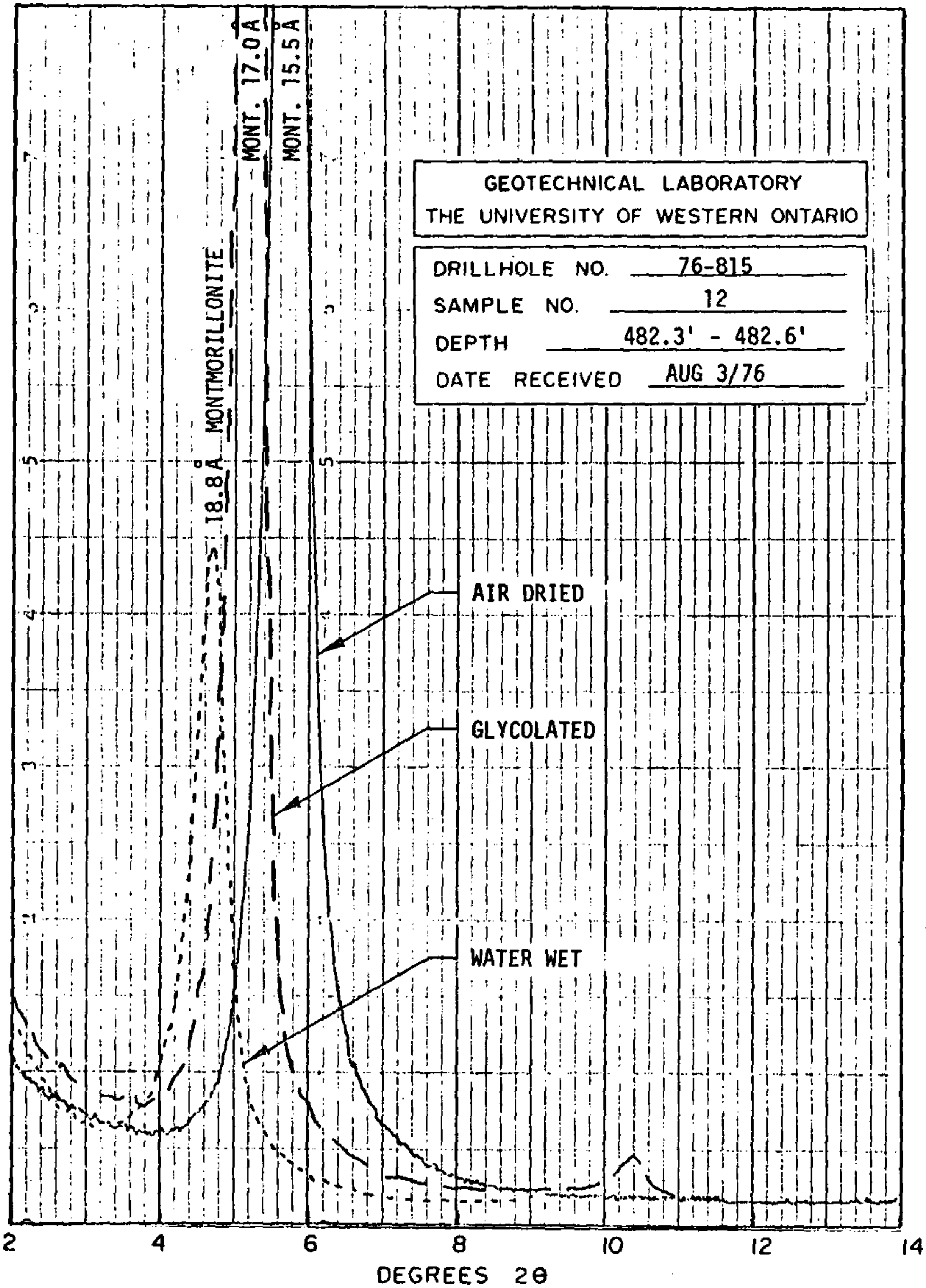
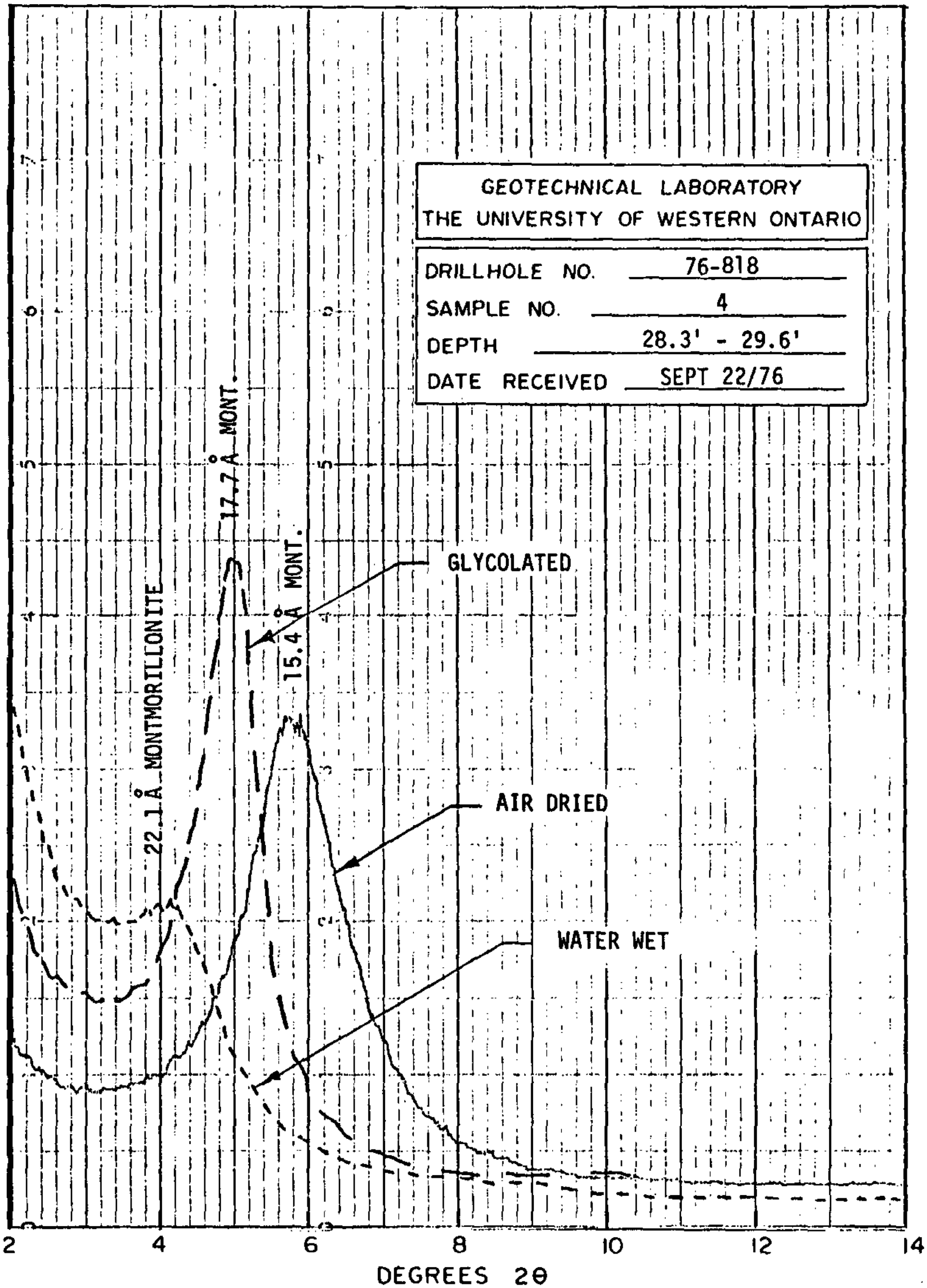


FIG. 4. X-RAY DIFFRACTION TRACE OF WHOLE SOIL POWDER FROM HAT CREEK.



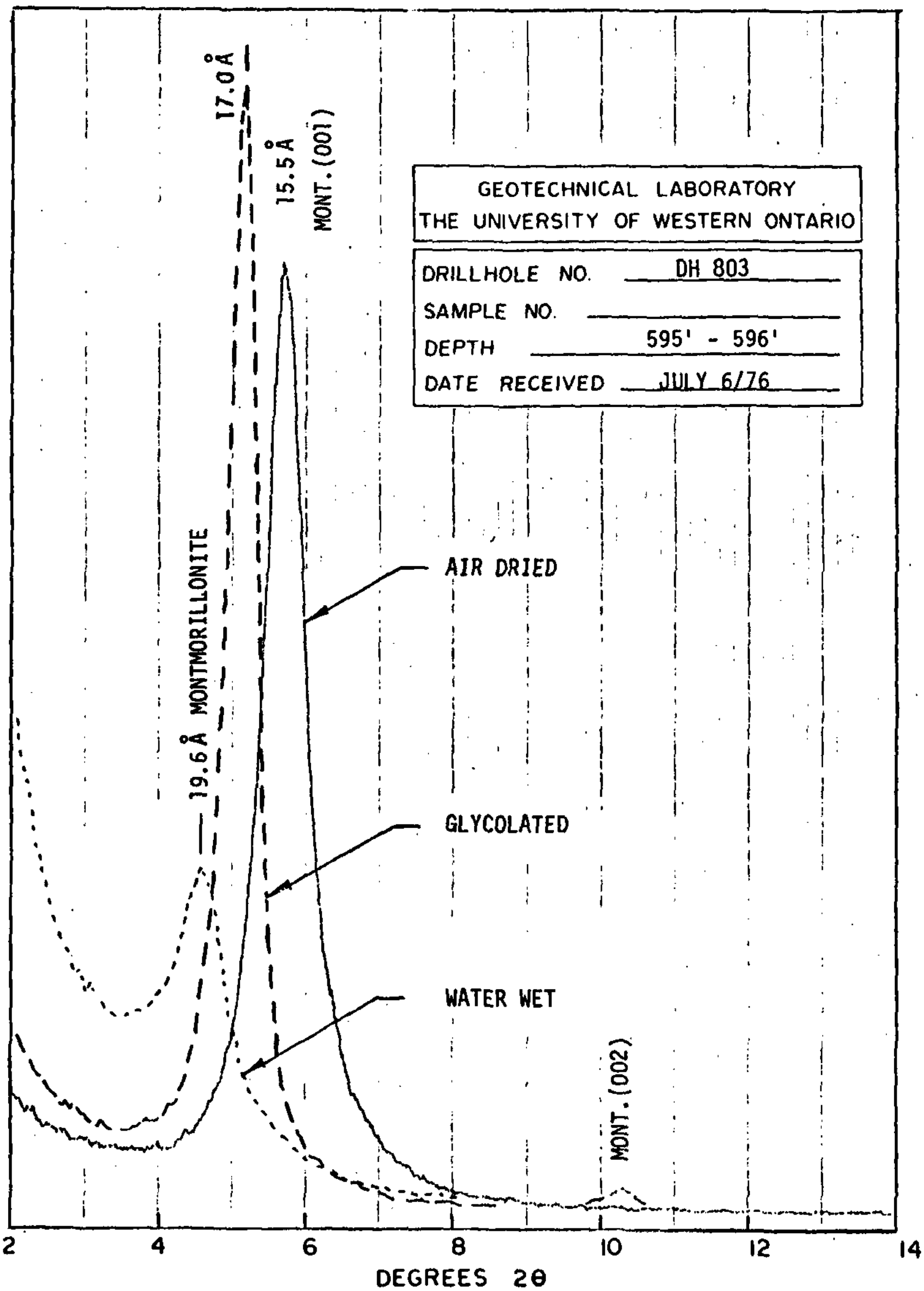
X-RAY DIFFRACTION TRACES OF < 2 μm, PREFERRED ORIENTED SPECIMENS FROM HAT CREEK.

FIG. 5.



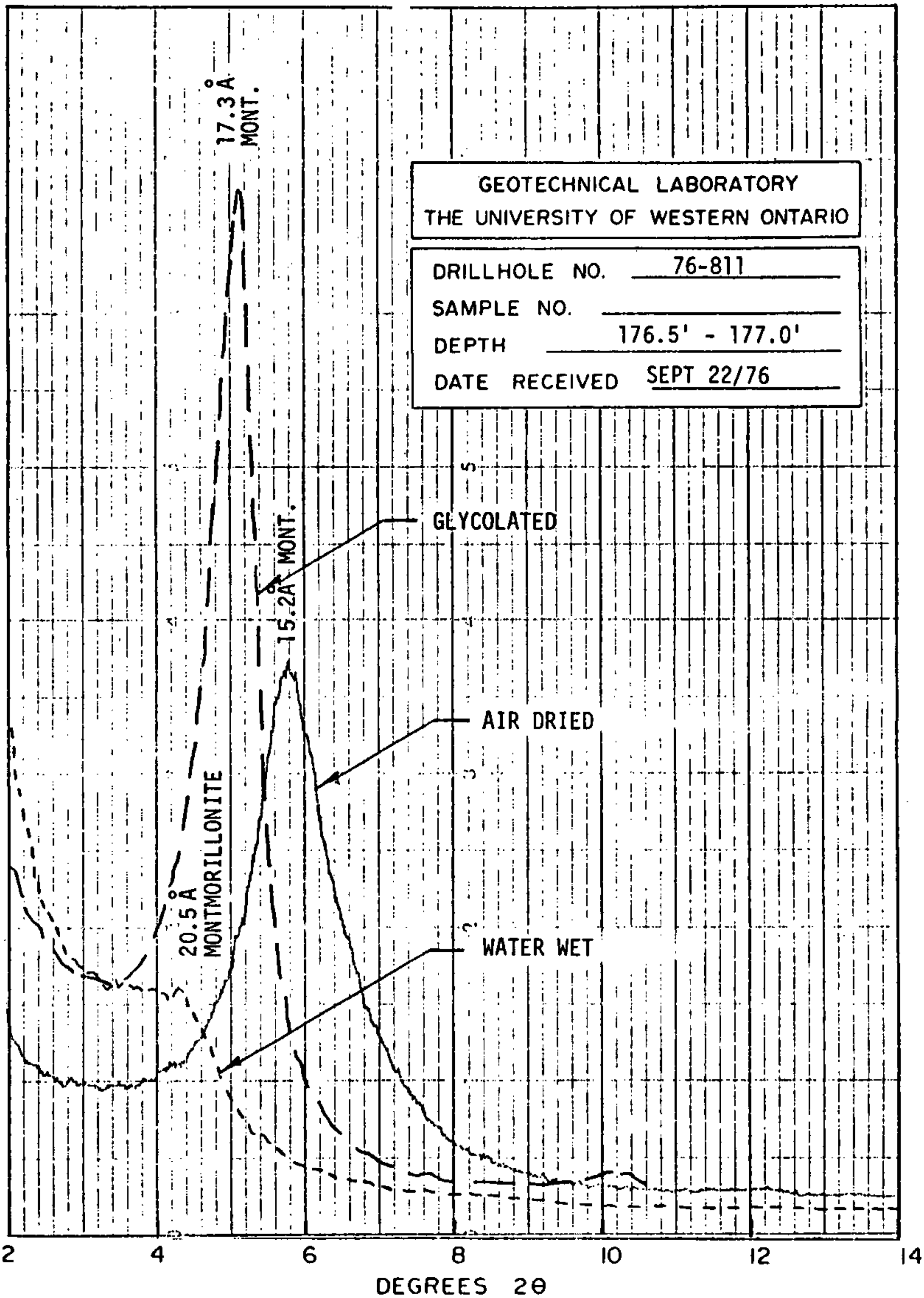
X-RAY DIFFRACTION TRACES OF < 2 μm, PREFERRED ORIENTED SPECIMENS FROM HAT CREEK.

FIG. 6.



X-RAY DIFFRACTION TRACES OF < 2 μm, PREFERRED ORIENTED SPECIMENS FROM HAT CREEK.

FIG. 7.



X-RAY DIFFRACTION TRACES OF < 2 μm, PREFERRED ORIENTED SPECIMENS FROM HAT CREEK.

FIG. 8.

R.M. QUIGLEY INC.
ROBERT M. QUIGLEY, PH.D., P.ENG.
President

1052 Kingston Avenue
London, Ontario, N6H 4C6

22 December 1976

Mr. G.E. Rawlings
Golder Brawner & Associates Ltd.
224 West 8th Avenue
Vancouver, British Columbia
V5Y 1N5

Dear Mr. Rawlings:

The Significance of Montmorillonite in the Hat Creek Stratigraphic Section

The purpose of this letter report is to discuss the engineering characteristics of the clay mineral montmorillonite with special reference to the Hat Creek project, British Columbia. Also discussed are the significant engineering aspects of the mineralogical and physico-chemical test results contained in the University of Western Ontario research report entitled "Preliminary Mineralogical and Physico-Chemical Analyses, Hat Creek Project, British Columbia" dated November 26, 1976.

This report has been prepared in accordance with verbal arrangements made at a meeting in your Vancouver offices on October 15, 1976 and follow-up letters dated October 20 and 25, and November 2, 1976.

Crystal Structure of Montmorillonite

The clay mineral, montmorillonite, is a very fine grained, 3-layer silicate of extreme activity relative to other clays. Its crystal structure and mineralogical characteristics are illustrated in Figure 1.

As can be seen from the sketch, each 3-layer unit is comprised of a gibbsite or aluminum hydroxide sheet (G) sandwiched between two silica sheets. The gibbsite sheet carries a net negative charge of -0.3 e.s.u.

... 2

per unit cell of 10 oxygens as shown by the structural formula. This charge is balanced by adsorbed, hydrated cations that occur both between the 3-layer units and in the double layer around the entire clay particle.

The number of cations present around a clay crystal to satisfy its negative charge is normally expressed in milliequivalents/100 g of clay and for montmorillonite is of the order of 100 m.eq./100 g.

The spacing between the 3-layer units normally varies from 16 to 18 Å damp and in the natural state. If dried completely, the spacing decreases to 9.3 Å. Some expandable montmorillonites in dilute, monovalent electrolytes may swell to several tens of angstroms so that, in effect, the bulk of the crystal structure is composed of weakly adsorbed water.

The very small size of the montmorillonite particles plus the interlayer area yield very high specific surfaces for montmorillonite (800 m^2/g). Generally speaking, the smaller the particles (i.e. the greater the specific surface) the more active the clay and the lower its residual friction angle.

One measure of the specific surface is the glycol retention value expressed in mg/g. Values for montmorillonite are normally about 250 mg/g, irrespective of the cations present. The ethylene glycol used for the retention measurements is believed to adsorb on the clay in a layer 2 molecules thick.

The combination of abundant interlayer and adsorbed double layer water is responsible for the high activity, marked swelling and low strength characteristics of montmorillonites.

It is particularly significant that the type of adsorbed cations and the concentration of the pore fluid electrolyte play an important role in establishing the physical properties of this clay. For example, Na^{+}-Mont swells much more than Ca^{++}-Mont because twice as many hydrated cations are required to satisfy the negative charges on the particles. Also, a dilute electrolyte serves to expand the double layer around the clays since there are very large concentration differences between the adsorbed cations in the double layer relative to the free water. Conversely a high electrolyte concentration (salty pore fluid) compresses the double layers, tends to cause flocculation and normally increases the strength of the soil.

... 3

If dried to fairly high temperatures (450 → 700°C), some montmorillonites become useful absorbents and decolourizing agents known as Fuller's earth.

Plasticity and Activity of Montmorillonite

Typical values for the liquid limit and activity of the most important clay minerals are tabulated as follows:

Clay Mineral	Pore Fluid Salt Conc.	ω_ℓ (%)	Activity (I_p ÷ % < 2 μm)
Kaolinite	Low → High	30 - 60	0.2 → 0.4
Illite & Chlorite	Low → High	50 - 130	0.5 → 1.0
Ca Mont	Low → High	100 - 250	1.5 → 1.8
Na Mont	* High	400 - 550	3.5 → 5
Na Mont	* Low	1000 - 1300	9 → 11

*High = 1 to 10^{-1} Normal; Low = 10^{-3} to 10^{-4} N.

The tabulation shows that montmorillonite is very active and plastic relative to the other clays. It also shows that Na montmorillonites are much more plastic and active than Ca Mg montmorillonites and that for dilute pore fluid concentrations, montmorillonite is a truly extraordinary material.

The very high liquid limit values for Na montmorillonite are caused by interlayer expansion that is inhibited by adsorption of cations such as Ca, Mg and K. Figure 2, adapted from Rosenqvist, 1957, illustrates this phenomenon for regimes of monovalent cations. The interlayer collapse caused by K^+ adsorption relative to Na^+ adsorption reduced the liquid limit of Rosenqvist's test clay from about 370 to 280. Similar collapse occurs with adsorption of Ca and Mg.

The data illustrated in Figure 3 were taken directly from Quigley et al, 1974 and serve to illustrate two points as follows:

1. The test montmorillonite, homoionic in Na^+, has an activity of 5.5 compared to about 1.7 for the clay homoionic in Mg^{++} (Salinity ~ 5 g/ℓ).

... 4

2. The mixtures of Mg illite and Na montmorillonite produced a strong curvature in the activity curve caused by adsorption of Mg onto the montmorillonite from the illite. In other words, preferential adsorption of Mg onto the Na montmorillonite significantly reduced its activity.

Figure 3 also shows values of glycol retention obtained on the illite-montmorillonite mixtures. It is significant that for 100% montmorillonite, similar glycol retentions were obtained for the Na and Mg clay states. The glycol retentions run on the Hat Creek clays are therefore a measure of specific surface and not greatly affected by interlayer or other swelling.

Although little if any illite was observed on the x-ray traces of the Hat Creek deposits, there is enough free Mg^{++} in the pore fluid to markedly reduce the liquid limits and activity values below those for a purely Na^{+} clay.

Permeability

The permeability of montmorillonite varies within the range of 10^{-9} to 10^{-8} cm/sec over a void ratio range of 2 to 10. Sodium montmorillonite is normally at least one order of magnitude less pervious than Ca Mg montmorillonites due largely to a greater proportion of the pore water being bound by adsorption around the monovalent Na cations.

For the sodium rich Hat Creek clays with a void ratio of about 1.0 (corresponding to $\omega_n = 35\%$), the permeability would probably be in the range of 10^{-10} cm/sec or less.

Residual Drained Strength Characteristics

The shear strength data plotted in Figure 4 were taken directly from Kenney, 1967 and serve to illustrate the residual friction angles characteristic of the main clay mineral groups. The very low values for montmorillonite are characteristic and caused by gliding along the inter-layer water between the 3-layer sheets.

The following tabulation shows the significance of both cation type and pore fluid concentration on the $\phi_{residual}$:

... 5

Clay	$S(g/\ell)$	ω_ℓ	ω_p	A_c	ϕ_{res}
Na Mont	0	~ 1500	55	~ 14	~ 4°
Na Mont	30	~ 800	45	~ 7	~ 8°
Ca Mont	0	795	47	7.4	~ 9°
Ca Mont	$CaSO_4$ sat'd	775	47	7.4	~ 10°

*Data taken from Kenney, 1967 who tested pure bentonite which may be more active than the Hat Creek clays. Valid for $\bar{\sigma}_N > 1$ ton/ft^2.

It is apparent that both cation type and concentration play a significant role on the values obtained for ϕ_{res}, the worst combination being a very low salinity and a Na^+ cation regime.

The strength of montmorillonite at very low effective stresses is a matter of conjecture in this writer's opinion. There seems to be some evidence that ϕ_{res} actually increases at low values $\bar{\sigma}_N$. However, fabric-strength studies by the writer suggest that clay platelet orientation plays a vital role in determining ϕ_{res}. Above $\bar{\sigma}_N$ values of 1 tsf, parallelism in the shear plane is highly developed. At very low stresses and higher water contents, the natural tendency of montmorillonite to form a gel of more random fabric may become a significant factor and the apparent effective stress control on c_d and ϕ_d may be overwhelmed by long range physico-chemical bonds.

Discussion of the Hat Creek Montmorillonites

The University of Western Ontario research report dated November 26, 1976 identified montmorillonite as the dominant clay mineral within the clayey strata above and below the coal measures at Hat Creek, B.C. In some beds, montmorillonite appeared to be the only mineral present whereas in others, variable amounts of carbonate, quartz and feldspar were present.

The mineralogical compositions of typical clayey strata appear to be more or less as follows:

1. Essentially pure montmorillonite with trace amounts of quartz and feldspar (< 10% primary silicates).
2. Montmorillonite with moderate amounts of quartz, feldspar and possibly α-cristobalite (10 to 30%).

3. Montmorillonite with low to moderate amounts of carbonate (1 to 10% siderite).

The pore water composition of the clayey strata appears to be roughly as follows:

Above the coal measures:

1. Salinity = 3.5 to 6.5 g/ℓ (less in glacio-lacustrine deposits)
2. Dominant cation is Na^{+} = 1.2 to 2.1 g/ℓ
   Significant cations are Mg^{++}(+ Ca) = 0.05 to 0.07 g/ℓ
3. Significant anions are $C\ell^{-}$ = 1 to 2 g/ℓ and probably some $SO_4^{=}$ (not determined).

Below the coal measures:

1. Salinity = 3.5 to 4.6 g/ℓ
2. Dominant cation is Na^{+} = 1.6 to 2.2 g/ℓ
   Significant cations are Mg^{++}(+ Fe) = 0.24 to 1.23 g/ℓ
3. Significant anions are $C\ell^{-}$ and probably $SO_4^{=}$ not determined.

From an engineering point of view, the "pure" or "near pure" montmorillonite beds are the most significant. The carbonate rich beds are less significant, since the carbonates act to some extent as inhibitors of swelling and produce relatively higher shear strengths. Those "near pure" montmorillonites with pore fluids of lowest salinity and highest sodium content are the most significant of all beds.

The total salinity values obtained to date (3.5 to 6.5 g/ℓ) are high enough that extraordinary swelling is probably not a problem unless fresh water leaching somehow proceeds within the deposit. Any strata that do exist with very low pore fluid salinities must be considered as extra-significant strata requiring special attention.

Although the dominant cation is Na^{+} in all pore fluid samples tested, there is enough Mg, Ca and Fe in the pore fluid to ensure a dominantly divalent regime in the double layer. This, along with the moderate salinities, should serve to effectively reduce the liquid limits and activity values of the Hat Creek clayey strata. Very approximate calculations using Gapon's exchange equation indicate that, with the pore fluid compositions so far obtained, the cations present in the double layers around the montmorillonite consist of:

Above the coal measures:

Divalent cations	60 - 70%
Monovalent Na^+	40 - 30%

Below the coal measures:

Divalent cations	75 - 85%
Monovalent Na^+	25 - 15%

These are very approximate since the pore fluid analyses were run on a soil wash rather than squeezed out pore water and the divalent cations may be more abundant than indicated above.

Although the writer did not feel authorized to make an extensive search for geological and mineralogical references to Cordilleran bentonites, some data for Wyoming and Alberta bentonites are readily available. For example, non-marine, late Cretaceous bentonites near Edmonton (Rosalind, Alberta) are discussed by Scarfe, 1973. The major components of these bentonites are cristobalite and montmorillonite, both believed to be in situ alteration products of the glassy volcanic ash deposits. Contaminants are commonly quartz, plagioclase feldspar plus biotite and occasionally siderite. Sodium is apparently the dominant cation along with calcium and magnesium which are indicated to comprise 20 to 55% of the cation exchange capacity.

Wyoming bentonites are described by Güven and Grim, 1972, and again the dominant constituents are 70% smectite and 20% α-cristobalite in the < 5 μm fraction. Quartz, feldspar and α-cristobalite dominate the coarse fraction (> 5 μm).

The Hat Creek deposits are quite similar to the above bentonites although α-cristobalite having a very strong 4.04 Å peak seems to be a rather less abundant constituent.

It is understood from telephone conversations with Mr. G. Rawlings that the index properties of the Hat Creek clayey strata have been determined to be more or less as follows:

... 8

$\omega_n \approx 35\%$

$\omega_\ell \approx 109$ to 178%

$\omega_p \approx 34$ to 39%

Activity = 0.75 to 1.4 (est'd by R.M. Quigley)

The values of liquid limit seem characteristic of montmorillonite with abundant adsorbed divalent cations and are thus consistent with the physico-chemical test results. The activity values are likewise consistent with the mineralogical and physico-chemical test results although somewhat on the low side.

Conclusion

It is hoped that the previous discussions, comments and questions have satisfied the requirements expected of this letter report.

Yours truly,
R.M. QUIGLEY INC.

R.M. Quigley

R.M. Quigley, P.Eng.
Designated Specialist
Civil Geotechnics
(Ontario APEO)

RMQ:em

R. M. QUIGLEY

Selected References

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MONTMORILLONOIDS

d variable (generally 16 to 18 Å damp)

Structural Formula

$$\left[(Al_{1.7}\,Mg_{0.3})^{-0.3}(Si_4)^{0}O_{10}\,(OH)_2\right]^{-0.3}(M)^{+0.3}$$

Classical montmorillonite

Properties and Characteristics

C.E.C. = 100 m.eq./100 g

Glycol retention = 250 mg/g

Specific surface = 800 m^2/g

Size of platy crystals:

Diameter = 0.1 to 1 μm

Thickness = $\frac{1}{100}$ diam

FIGURE 1. THE NATURE OF MONTMORILLONITE

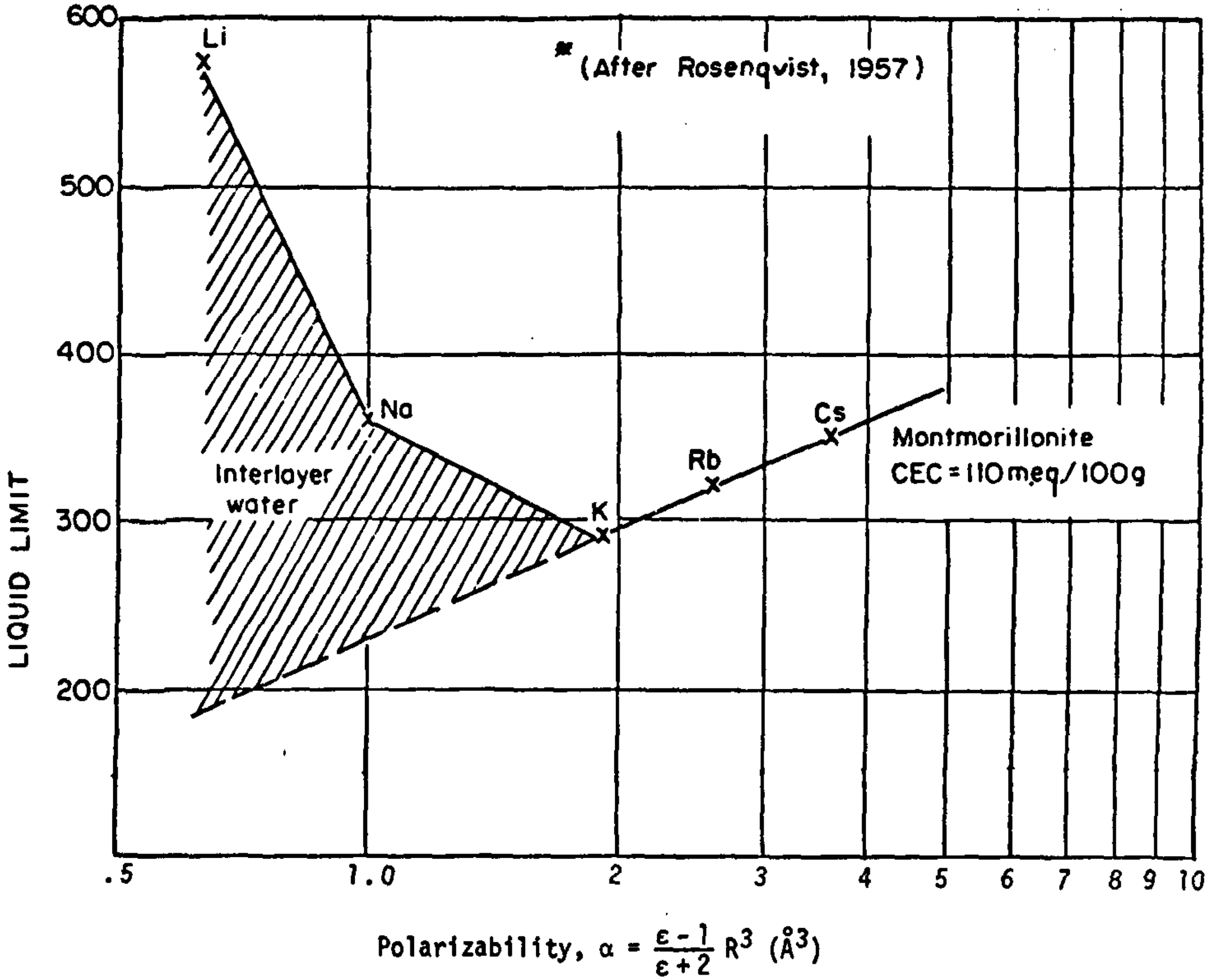


FIGURE 2. VARIATION IN LIQUID LIMIT OF MONTMORILLONITE WITH VARIOUS MONOVALENT CATIONS

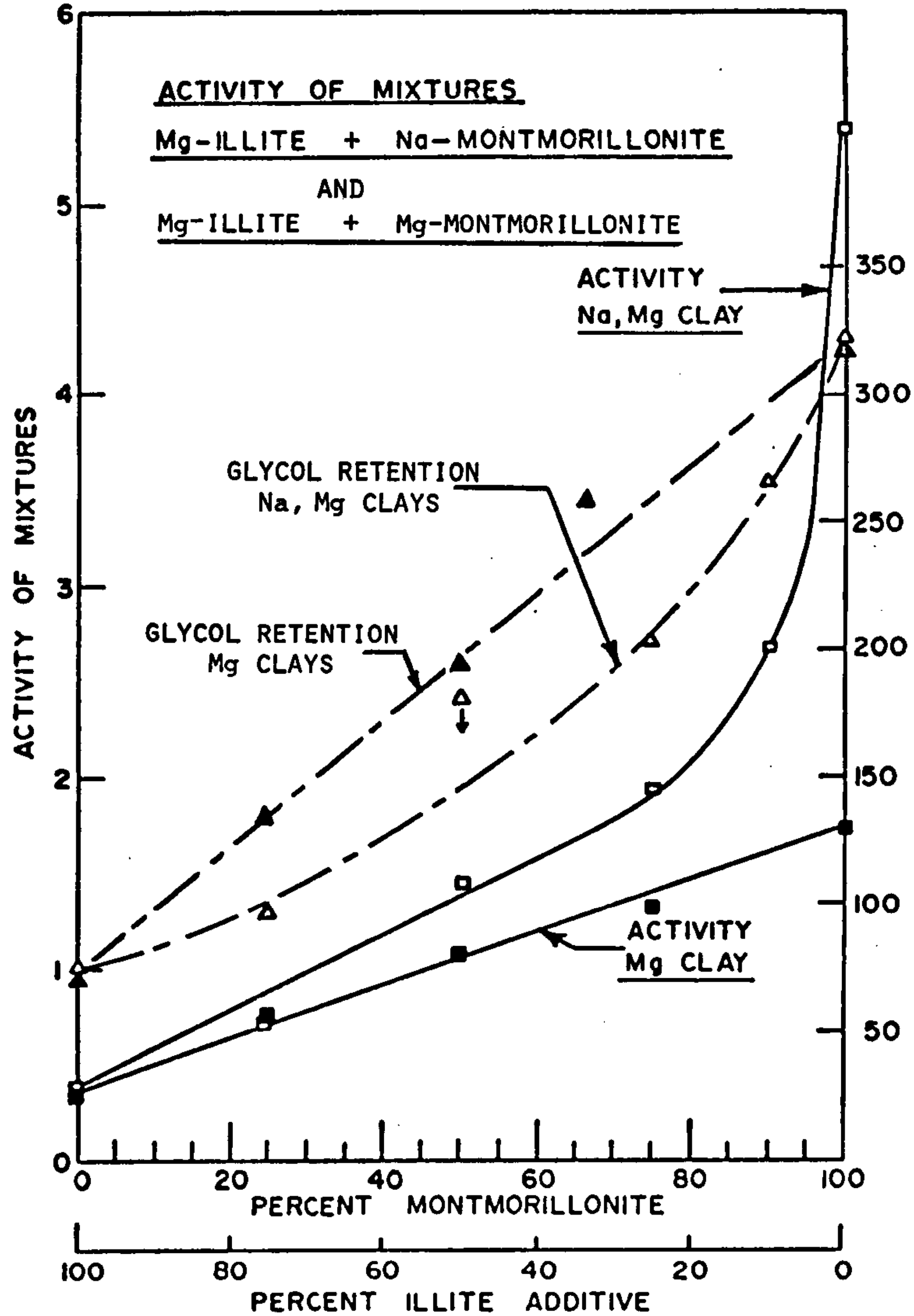


FIGURE 3. ACTIVITY AND GLYCOL RETENTION OF MIXTURES OF ILLITE AND MONTMORILLONITE (after Quigley, Kubo and Hamilton, 1974)

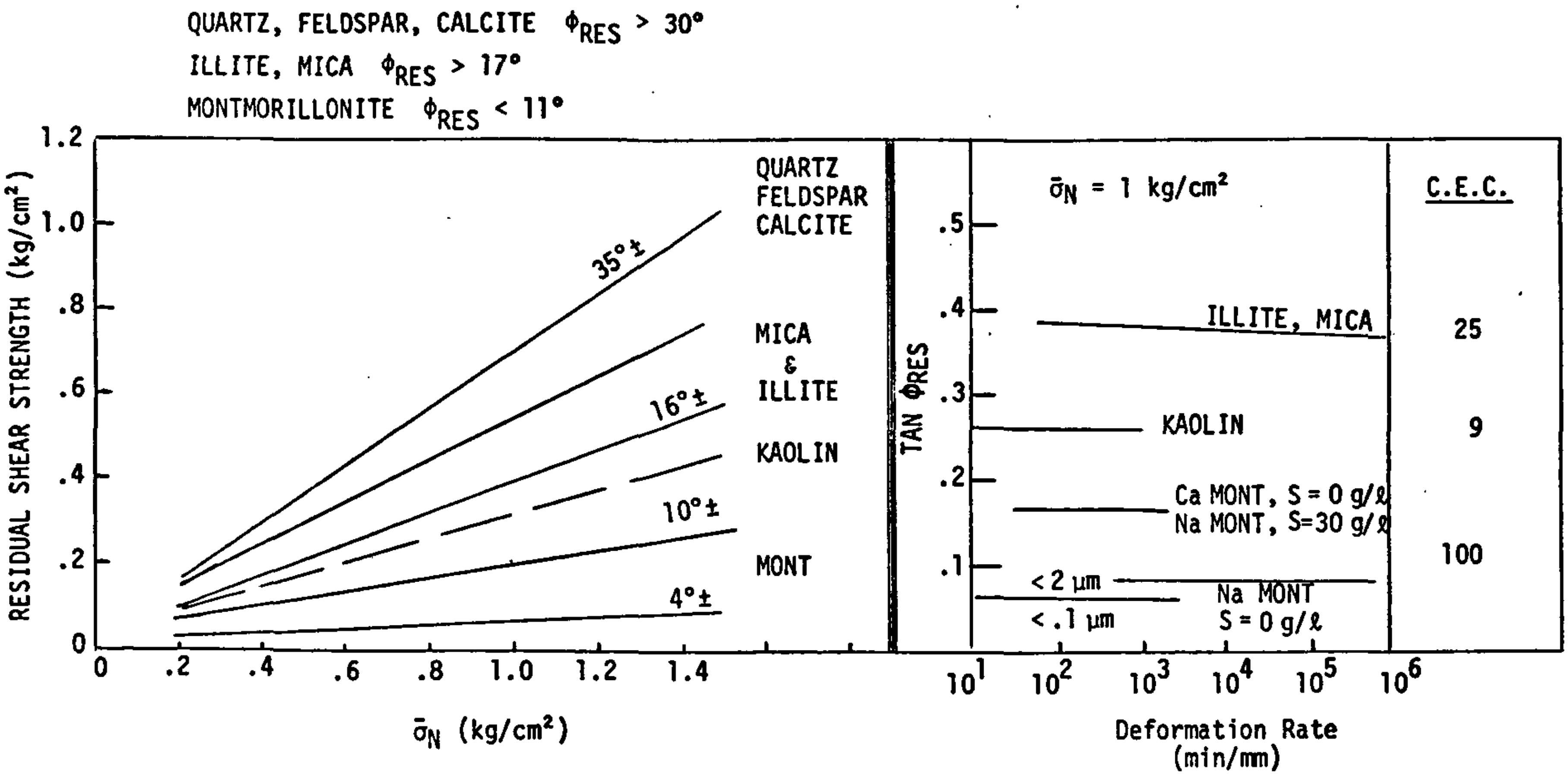


FIGURE 4. RESIDUAL DRAINED STRENGTHS OF THE CLAY MINERAL GROUPS
(adapted from Kenney, 1967)

The University of Western Ontario

Faculty of Engineering Science
London, Canada
N6A 5B9

11 January 1977

Mr. G.E. Rawlings
Golder Brawner & Associates Ltd.
224 West 8th Avenue
Vancouver, British Columbia
V5Y 1N5

Dear Mr. Rawlings:

Physico-chemical and x-ray testing -
direct shear specimen from Hat Creek

We have now completed our physico-chemical analyses on your direct shear specimen identified as follows:

DH 76-806
Sample 21, Depth 171.5 - 176.3 ft.

Our testing has included the following items:

1) X-ray powder pattern of the whole soil
2) X-ray diffraction of oriented < 2 µm fraction, Wet PO, ADPO and GPO
3) Salinity and pH
4) Analysis for pore water Na^+, Ca^{++} and Mg^{++}.

Results

The x-ray powder pattern shows the sample to consist of the following minerals in their approximate order of abundance:

Montmorillonite	-	dominant
Feldspar and cristobalite	-	moderate
Quartz	-	moderate to minor

The actual x-ray trace is quite similar to that shown in Fig. 2 of our final report dated November 26, 1976. Carbonate peaks could not be identified on the trace indicating little if any siderite.

The x-ray diffraction traces on the oriented fines yielded traces similar to those shown in Fig. 7 of our November 26, 1976 report. Strong peaks at 20.1 Å (water wet), 15.2 Å (air dried) and 17.1 Å (glycolated) were obtained indicating a nearly pure montmorillonite since peaks at 10 Å and 7 Å were not present.

The pore water salinity, assuming a natural water content of 35%, is about 4.1 g/ℓ which is similar to the salinities throughout the section as documented in Table III of our November 26, 1976 report. A measured pH of 9.6 is somewhat higher than the typical 9.3 reported on two other samples located stratigraphically below the coal measures.

The cation analyses yield values for Na, Ca and Mg as follows:

$$Na^{+} = 2.1 \text{ g/}\ell$$
$$Ca^{+} = .016 \text{ g/}\ell$$
$$Mg^{+} = .014 \text{ g/}\ell$$

The sodium value is close to measured values of 1.59 to 2.13 on three other samples below the coal. The values for calcium are very low as in the previous testing. The value for magnesium is much lower than the 0.5 to 0.8 g/ℓ obtained on three other samples below the coal.

Comments

On the basis of the above analyses, it is suggested that this clay stone is essentially sodium saturated and with swelling permitted would yield a residual friction angle of not greater than 7 or 8 degrees.

Lower values would not be expected unless the salt content is reduced below its in situ value of 4.1 g/ℓ.

The writer has reviewed the unsigned reports on the direct shear data supplied to him and concurs with their author that the undisturbed sample did not swell due to the exceptionally low permeability of the bentonitic clay stones. The writer also agrees that complete remoulding at a higher moisture content (more or less in equilibrium with the effective stress on the failure plane at failure) is the best way to establish the lower bound of the friction angle. The writer has found that removal of the grit from soft samples is often necessary to ensure that the lower bound friction values are obtained.

Questions which should be asked regarding direct shear procedures are as follows:

1. Did the clay actually reach residual strength in terms of both clay platelet parallelism and moisture content change?

    (a) For hard, over consolidated clays like those from Hat Creek, the moisture content should increase greatly on the failure plane.

    (b) For soft, normally consolidated clays rich in montmorillonite, the moisture content will decrease on the failure plane yet parallelism may cause a net loss of strength.

2. With regard to the above, an attempt should be made to obtain the moisture content on the actual failure plane and a plot of drained strength vs water content plotted as a control against plots of the strength envelope ($\bar{\sigma}_{ff}$ vs τ_{ff}).

3. Did the presence of grit rolling or grinding along between the halves of the direct shear box create an artificial ϕ? Similarly, was there unnatural gouging by large sized particles (sand) that would create a ϕ_{res} larger than representative of the field ϕ_{res}?

4. Was the rate of strain slow enough to ensure drainage (i.e. no excess pore pressures during shear)? Indeed, is it possible to shear a sample of hard Na bentonite by direct shear and obtain no excess pore pressures?

5. At low stress levels and very low strain rates, will the natural thixotropic properties of the bentonitic clays overwhelm the usual effective stress type of relationships commonly obtained on clayey soils?

Although these comments must necessarily be incomplete at this early phase in the study of these complex clay stones, it is hoped that they meet the present needs of the project.

Yours sincerely,

R.M. Quigley

R.M. Quigley, P.Eng.
Professor

RMQ:em

SUMMARY OF X-RAY DIFFRACTION ANALYSES
CARRIED OUT BY THE
UNIVERSITY OF BRITISH COLUMBIA
DECEMBER, 1966

Hole No.	Depth (Ft.)	Quartz	Kaolinite	Bentonite	Siderite	Felspar	Epidote
76-123	399 -403	11	3	69	13	4	-
76-124	348 -350	9	10	71	-	10	-
76-135	296 -301	13	47	34	-	6	-
76-135	534.1-534.5	31	37	26	6	-	-
76-135	557.5-557.7	24	27	39	-	10	-
76-135	661.0-661.3	34	52	14	-	trace	-
76-136	219 -221	8	11	79	-	2	-
76-144	442	49	15	29	-	7	-
76-191	238.6-238.9	8	55	22	trace	15	-
76-191	298.2-298.5	20	48	19	-	13	-
		12	58	30	-	-	-
76-191	388.1-388.4	11	68	15	-	6	-
76-191	464.1-465.0	17	47	36	trace	-	-
76-191	532.8-533.1	22	29	38	-	11	-
76-191	645.0-645.5	19	51	-	19	-	11
76-191	706.2-706.5	47	53	trace	-	-	-
76-191	744.7-745.0	43	67	-	-	-	-
76-191	809.1-809.5	45	51	-	4	-	-
		46	44	-	-	8	-
76-191	950.2-950.8	38	62	trace	-	-	-
76-191	1285.6-1286.0	35	65	-	-	-	-
		43	54	-	3	-	-

Note: Accuracy for quartz, kaolinite and felspar ± 3%, for bentonite ± 5%.

COPY OF ORIGINAL LETTER

CORE LABORATORIES-CANADA LTD.
Petroleum Reservoir Engineering

P.O. Box 5670, Postal Station "A"
Calgary, Alberta T2H 1Y1
Telephone: 253-3391

July 7, 1976

Birtley Engineering (Canada) Ltd.
P. O. Box 5488, Postal Station "A"
Calgary, Alberta
T2H 1X9

Attention: Mr. Don F. Symonds

Re: Analysis of Clay Samples from
B.C. Hydro Sample A-7365/66
Our File Number: 7061-6268

Gentlemen:

The analysis of the above samples showed the following.

Sample 1:

Water Content	6.3%
Mineral Content	83.3%

X-Ray Diffraction Analysis of Mineral Portion

Quartz	14
Feldspar	9
Pyrite	6
Siderite	4
Kaolinite	57
Montmorillonite	10

Sample 2:

Water Content	6.3%
Mineral Content	83.8%

X-Ray Diffraction Analysis of Mineral Portion

Quartz	18
Feldspar	9
Pyrite	5
Siderite	5
Kaolinite	50
Montmorillonite	13

....2

Birtley Engineering (Canada) Ltd. 7061-6268

Sample 3:

Water Content	7.6%
Mineral Content	80.7%

X-Ray Diffraction Analysis of Mineral Portion

Quartz	16
Feldspar	8
Pyrite	Trace
Siderite	Nil
Kaolinite	60
Montmorillonite	16

Sample 4:

Water Content	4.0%
Mineral Content	94.8%

X-Ray Diffraction Analysis of Mineral Portion

Quartz	25
Feldspar	20
Pyrite	Nil
Siderite	Nil
Kaolinite	48
Montmorillonite	7

The samples were dried in a constant humidity oven at 145°F and 50% relative humidity for four days. A Dean and Stark analysis was performed to measure the remaining water; an ash analysis to determine the mineral content and an x-ray diffraction analysis to determine the type and quantity of the clay components.

Assuming that all the water present is intramicellar (inter-layer) water associated with the montmorillonite, the ratio of water to montmorillonite is 0.756/1, 0.579/1, 0.589/1 and 0.602/1 for sample one to four, respectively. By calculating, the molecular ratio between the water and montmorillonite are 15.1, 11.6, 11.8 and 12.0 for samples one to four, respectively.

The above calculations are based on the assumption that all the water is present as intramicellar water associated with the montmorillonite. The ratio of water to montmorillonite is higher than published values (0.15 to 0.20/1) for samples dried at 145°F and 50% relative humidity. This may indicate that all the free water had not been removed or that a portion of the water had been present as intermicellar (inter-particle) being adsorbed between the montmorillonite particles rather than being adsorbed within the particles.

Yours truly,
CORE LABORATORIES-CANADA LTD.

J. R. Jackson

JRJ:lr

APPENDIX 4

UNIAXIAL COMPRESSION TESTS

APPENDIX 4

UNIAXIAL COMPRESSION TESTS

Uniaxial compressive strength testing was carried out in conjunction with the field drilling operations in Hat Creek to assess the variation in strengths of the rock types encountered. On site testing was performed so that the prepared samples would be as fresh as possible avoiding moisture loss. The results of the testing were correlated to such factors as rock type, water content, grain size, and gross structural features. The mode of failure of each specimen was also noted.

DESCRIPTION OF TESTS

The test equipment included a manually operated hydraulic loading ram, a loading frame, a 10,000 lb. capacity proving ring and dial gauge, spherical platens to ensure that load application was perpendicular to the sample surface, and several sizes of flat platens.

The cylindrical rock specimens were cut with a length to diameter ratio of approximately 2, but not exceeding 2.5 nor less than 1.5. Careful end preparation of the sample was essential to ensure a smooth planar loading surface perpendicular to the axis of the specimen. In cases where the rock material was too weak or brittle to allow adequate end preparation, the ends of the specimen were cast in a mold of liquid sulfur, which hardened rapidly to a smooth planar surface. The effect of the sulfur was to minimize stress variations across the ends of the sample and thus ensure a uniform axial load.

Prior to testing, the initial length and average diameter of the samples were measured. Loading was applied relatively slowly to allow "seating" of the platens against the ends of the specimen. When "cracking" of the specimen was heard the loading was slowed to allow the material time to adjust. When load drop off occurred, the load was noted and allowed to fall off to a stable value. At this point, depending on whether fracture of the specimen had occurred, the sample was reloaded until it could take no further load. The maximum load that the sample was capable of sustaining was judged to be the ultimate uniaxial compressive stress.

RESULTS

The results of the uniaxial compressive strength tests are shown in Table A4-1.

The salient features to be noted are as follows:

1. Coal strengths varied from 400 to 2,500 psi. There is no relationship between the compressive strength and depth. The strength is more related to composition, texture, water content, and orientation of discontinuities relative to the direction of loading.
2. Conglomerate varied considerably in strength depending upon the degree of cementation present. A range in uniaxial compressive strength from 60 to 560 psi was noted for badly cemented and clayey conglomerate, 560 to 1,600 psi for firmly cemented conglomerate, and 1,600 - 1,960 psi for strongly cemented conglomerate.
3. The strength of the sandstones depends largely on the nature of the cement, degree of weathering and density of packing. The strengths obtained varied from 150 to 860 psi and are low in relation to fresh unweathered sandstones measured elsewhere.
4. Siltstone strengths ranged from 80 to 520 psi. Clayey siltstone samples with clay layers failed along the layers, and gave very

low compressive strengths varying from 7 to 40 psi. No consistent relationship between unconfined compressive strength and water content was discerned.

5. Claystone strengths varied from 10 to 140 psi and results were very consistent. There is a definite tendency for strength to decrease with increasing water content. Many of these samples were highly bentonitic.

TABLE A4-1

HAT CREEK GEOTECHNICAL STUDY

UNIAXIAL COMPRESSION TEST RESULTS

Sample	Hole No.	Depth ft.	H/Ø	Co Psi	Description
1	76-809	433	1.6	447	Tuffaceous siltstone.
2	76-809	436	2.0	285	Somewhat tuffaceous, bentonitic siltstone.
3	76-809	436	1.6	383	Greenish, highly tuffaceous siltstone.
4	76-809	443	1.9	238	Greenish, highly tuffaceous w. f. grained cement.
5	76-816	752	2.1	856	M. grained, granodioritic sandstone w. coaly debris.
6	76-816	768	2.0	835	M-f grained, coaly sandstone.
7	76-816	768	2.1	766	M-f grained, coaly sandstone.
8	76-816	748	2.0	796	M. grained, grey sandstone.
9	76-816	843	2.3	J3286	Banded basalt w. chlorite amygdales.
10	76-816	?	2.0	1721	Sheared or flow banded volcanic rock.
11	76-816	783	2.0	1924	Sheared or flow banded volcanic rock.
12	76-151	789	1.8	2479	Coal
13	76-151	855	2.0	1495	Coal
14	76-149	1539	1.9	350	Siltstone?
15	76-149	1533	1.9	800	Claystone?
16	76-149	1523	2.2	807	Siltstone?
17	76-809	216	2.1	17	Possible slide plane, bentonitic gravel.
18	76-809	216	2.0	7	Bentonitic claystone w. soft layer.
19	76-809	218	2.1	35	Bentonitic claystone w. soft layer.
20	76-809	218	2.2	42	Bentonitic tuff w. bentonite seams.
21	76-809	130	1.5	114	Carbonaceous bentonitic siltstone.
22	76-809	49	2.1	42	Bentonitic siltstone w. carbonaceous partings.
23	76-809	475	2.1	703	Altered tuffaceous sandstone.
24	76-809	475	2.0	410	Altered tuffaceous sandstone.
25	76-809	462	1.9	239	Altered tuffaceous sandstone.
26	76-809	442	2.1	102	Bentonitic siltstone.
27	76-809	416	2.0	682	Gravelly sandy aggregate of volcanic debris w. zeolite.
28	76-809	401	2.2	519	Tuffaceous silty sandstone.

UNIAXIAL COMPRESSION TEST RESULTS (Continued)

Sample	Hole No.	Depth ft.	H/Ø	Co Psi	Description
29	76-809	402	2.1	466	Tuffaceous silty sandstone.
30	76-809	386	2.0	259	Tuffaceous silty sandstone.
31	76-809	395	2.0	347	Tuffaceous silty sandstone.
32	76-809	371	2.0	1454	Meta-basalt w. pyroclastic layer.
33	76-809	361	2.0	125	Coarse sandstone & bentonitic siltstone, prob. agglomeratic.
34	76-808	45	1.8	57	Carbonaceous siltstone, w. resin beads.
35	76-808	46	2.0	55	Slide debris - carbonaceous, bentonitic, tuffaceous siltstone.
36	76-808	47	2.0	90	As above with carbonaceous debris.
37	76-808	42	1.9	64	Bentonite
38	76-808	25	2.1	104	Bentonitic claystone.
39	76-808	27	2.1	83	Bentonite
40	76-810	115	2.0	57	M. grained, clayey sandstone.
41	76-810	167 ?	2.0	33	Altered tuff.
42	76-814	362	2.0	50	Bentonitic claystone.
43	76-816	641	2.0	1300	Agglomerate
44	76-816	681	2.1	708	Tuffaceous conglomerate-agglomerate.
45	76-816	718	2.1	1005	Tuff-tuffaceous sandstone.
45A	76-816	675	1.7	1952	Tuffaceous sandstone showing graded bedding.
45B	76-816	716	2.0	1036	Tuffaceous sandstone.
46	76-814	363	2.0	107	Claystone.
47	76-814	364	1.9	137	Fine grained tuff.
48	76-814	366	1.9	225	Claystone.
49	76-814	395	2.1	115	Bentonitic tuffaceous, sandy siltstone.
50	76-810	265	2.0	81	Sheared, carbonaceous, clayey siltstone.
51	76-810	218	2.1	229	Tuffaceous, coarse grained siltstone.
52	76-814	462	2.0	290	Tuffaceous, medium grained siltstone.
53	76-810	224	1.9	290	Tuffaceous, medium grained siltstone.
54	76-814	452	2.2	78	Bentonitic, silty claystone.
55	76-814	484	2.2	103	Carbonaceous, clayey siltstone.
56	76-814	596	2.1	484	Tuff w. coal partings.
57	76-814	596	2.2	492	Tuff w. coal partings.

UNIAXIAL COMPRESSION TEST RESULTS (Continued)

Sample	Hole No.	Depth ft.	H/Ø	Co Psi	Description
58	76-814	514	2.1	116	Sheared, carbonaceous siltstone.
59	76-814	555	1.9	158	Sheared, carbonaceous siltstone.
60	76-814	640	1.7	125	Silty claystone.
61	76-814	525	2.2	282	Silty coal.
62	76-814	676	1.8	445	Tuffaceous sandstone.
63	76-814	669	2.0	206	Coal - Failed on sheared bedding.
64	76-811	118	1.7	37	Bentonitic siltstone w. carbonaceous layer.
65	76-811	118 ?	2.0	59	Bentonitic siltstone (dried).
66	76-811	88	2.0	44	Bentonitic siltstone w. coaly parting.
67	76-811	118	2.2	113	Bentonitic siltstone (dried).
68	76-811	88	1.6	47	Bentonitic siltstone w. coaly parting.
69	76-811	118	1.9	80	Bentonitic siltstone (dried).
70	76-811	107	2.0	162	Interbedded, bentonitic sandstone/siltstone.
71	76-811	107	2.1	167	Interbedded, bentonitic sandstone/siltstone.
72	76-811	142	2.0	50	Disturbed bentonitic, silty gravel - slide.
73	76-811	211	2.3	235	Bentonitic, silty sandstone.
74	76-811	70	2.0	40	Bentonitic siltstone w. coaly parting.
75	76-811	265	2.2	174	M-c. grained friable sandstone.
76	76-811	230	2.0	93	Bentonitic, silty sandstone.
77	76-169	388	2.0	2496	D zone - clean durain.
78	76-168	305	2.2	706	D zone - clean durain.
79	76-169	382	1.8	998	D zone - clean durain.
80	76-168	288	2.1	589	Slightly silty coal.
81	76-813	530	2.4	8	Brecciated & sheared, bentonitic siltstone.
82	76-813	575	2.2	325	Bentonitic siltstone.
83	76-813	583	2.4	96	Bentonitic conglomerate.
84	76-813	568	2.2	70	Bentonitic conglomerate.
85	76-813	546	2.3	340	Bentonitic sandstone intact.
86	76-168	408	2.2	599	Vitrain coal sheared.
87	76-168	464	2.0	257	Durain/vitrain silty coal.
88	76-168	368	2.2	817	Silty durain coal.
89	76-169	396	2.2	847	Clarain coal intact.

UNIAXIAL COMPRESSION TEST RESULTS (Continued)

Sample	Hole No.	Depth ft.	H/Ø	Co Psi	Description
90	76-813	601	2.2	325	M. grained sandstone w. coaly parting.
91	76-813	610	2.2	359	Carbonaceous siltstone - Failed along bedding.
92	76-168	656	2.2	1557	Vitrain coal intact.
93	76-813	620	2.3	420	Slightly sheared, carbonaceous siltstone.
94	76-168	607	2.2	1780	Vitrain coal intact.
95	76-168	636	2.0	2405	Slightly silty vitrain coal.
96	76-813	590	2.3	459	Bentonitic f. grained sandstone.
97	76-817	73	2.3	1398	Clarain coal (D).
98	76-817	87	1.9	919	Silty durain coal.
99	76-171	391	2.3	442	Sheared durain & clarain coal.
100	76-168	686	2.3	1694	Vitrain, slightly sheared.
101	76-168	739	2.3	1164	Silty durain intact.
102	76-168	757	2.2	1438	Silty durain intact.
103	76-172	336	2.2	1814	Silty durain intact.
104	76-172	376	2.1	1061	Silty durain intact.
105	76-172	295	2.2	1506	Sheared durain.
106	76-812	72	2.3	53	Bentonitic, sandy siltstone.
107	76-817	201	2.2	805	Silty durain (D).
108	76-817	272	2.5	710	Durain sheared (D).
109	76-817	224	2.3	519	Silty durain & vitrain (D).
110	76-817	415	2.1	1197	Clarain (D).
111	76-812	198	2.2	66	Highly bentonitic, clayey siltstone.
112	76-817	436	2.2	707	Carbonaceous siltstone.
113	76-817	386	2.5	1028	Clarain intact.
114	76-812	123	2.2	133	Bentonitic, silty sandstone, intact.
115	76-812	157	2.0	27	Highly sheared, bentonitic, silty claystone.
116	76-812	112	2.0	38	Claystone?
117	76-812	170	2.2	29	Claystone?
118	76-812	?	2.0	18	Highly sheared, bentonitic, silty claystone.
119	76-812	243	2.1	60	Bentonitic gravel.
120	76-812	294	2.2	172	Slightly tuffaceous sandstone.
121	76-812	285	2.3	83	Bentonitic, sandy siltstone/sandstone intact.
122	76-812	328	2.3	510	Tuffaceous conglomerate.

UNIAXIAL COMPRESSION TEST RESULTS (Continued)

Sample	Hole No.	Depth ft.	H/Ø	Co Psi	Description
123	76-812	346	2.1	276	Bentonitic sandstone.
124	76-812	285	2.2	359	Bentonitic siltstone.
125	76-812	258	2.1	113	Clayey, silty sandstone.
126	76-812	346	2.2	340	Bentonitic sandstone (dried for 17-18 hrs.).
127	76-812	381	2.3	634	Bentonitic tuff.
128	76-812	361	2.2	355	M. grained bentonitic sandstone.
129	76-812	381	2.2	321	Bentonitic conglomeratic tuff.
130	76-812	389	2.2	887	Bentonitic conglomerate.
131	76-812	258	2.3	107	Bentonitic sandstone.
132	76-812	361	2.1	522	M. grained bentonitic sandstone.
133	76-812	346	2.0	738	Bentonitic sandstone (dried for 20 hrs.).
134	76-812	328	2.5	1963	Calcareous cemented.

APPENDIX 5

GEOHYDROLOGIC DATA

APPENDIX 5

GEOHYDROLOGIC DATA

Appendix 5 contains the following information:

I) Summary hydrologic logs of all holes in which hydrologic installations and tests were made.

II) Description of procedure used for carrying out in situ falling head permeability tests in standpipe piezometers.

III) Installation and monitoring of piezometers.

IV) Cantest Ltd. report on the inorganic chemical analyses of water samples.

1) Summary Hydrologic Logs

I) HYDROLOGIC LOGS

The following logs summarize hydrologic information on selected boreholes where good subsurface hydrologic data has been obtained. The abbreviated lithology is based on data supplied from drillers, core log sheets and drill logs (see Appendix 1).

In order to show all data in a compact log it was necessary to use a number of abbreviations and a symbolic notation. The following notes explain these abbreviations. The note numbers correspond to the numbers shown in parenthesis at the head of each column in the following hydrologic logs:

1. Lithology Abbreviations Used in Logs

Rock/Soil Type:

Slst = siltstone

Sst = sandstone

Clst = claystone

Congl = conglomerate

2. Datum

Unless otherwise stated all depth measurements are given in feet relative to existing ground level.

T.D. = total depth drilled.

3. Construction

a) Hole

drilled hole casing removed

drilled hole casing left in place

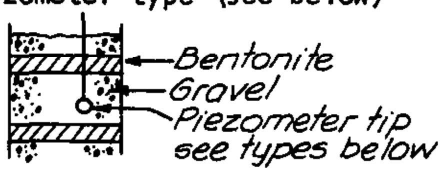
drilled open hole

drilled hole known to have squeezed in

Standard Double Seal Piezometer Arrangement

236 depth to centre of piezometer inlet

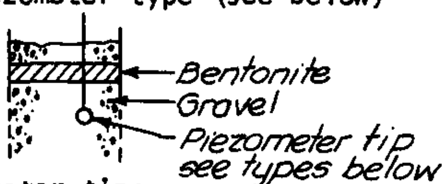
piezometer type (see below)



Standard Top Seal Piezometer Arrangement

236 depth to centre of piezometer inlet

piezometer type (see below)



Types of piezometer tip:

Type 1 - perforated 3/4" ϕ PVC pipe (approx. 5 ft. long)
- wrapped with permeable fabric

2 - Thor pneumatic piezometer

3 - Slotted 1.25 in ϕ PVC pipe (approx. 2 ft. long)

b) <u>Types of Backfill</u> (note only fills over 5 ft. thick are shown)

gravel

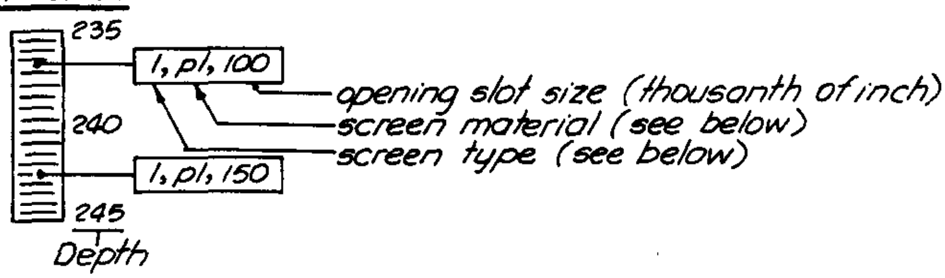
soil - local material (undifferentiated)

sand

bentonite

cement grout

c) <u>Well Screen</u>



Screen Type: 1) Continuous wire wound

2) Slotted horizontally

3) Slotted vertically

4) Louvered openings

Screen Material: pl = plastic

st = steel

ss = stainless steel

4. WL = Water level measured when drilling had reached indicated depth.

5. WC = Water content of soil, as determined in laboratory (%).

6. Other : fl = water flowing over top of casing

Lw = losing water

Mw = making water

7. SWL = Static water level in piezometer/well after the ground water had recovered from drilling operations (October, 1976). Positive values indicate artesian heads (i.e. above datum). These static water levels are equivalent to total piezometric heads in all piezometers.

8. D = Depth range for permeability test

K = Average formation permeability determined (cm/sec)

M = Method used to determine permeability

p = Packer test using falling head method

f = Falling head test in piezometer

w = Pumping test

9. Elevations: are of three types:

Type 1 estimated from plan

Type 2 measured with an altimeter

Type 3 surveyed level

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-134
Sheet 1 **of** 1

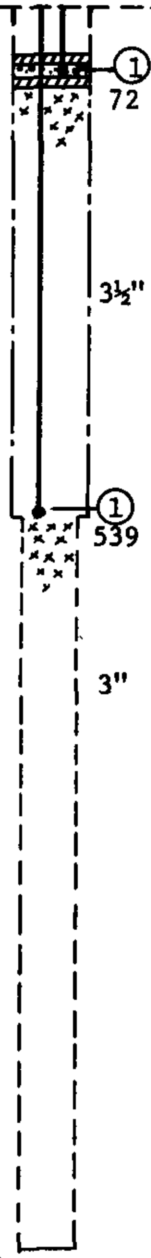
Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 38 Wireline
Drilling Fluid Bentonitic Mud

Coordinates E 17991
N 75987
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3334
Type No. (9) 3
Purpose of Hole Geotechnical Study

Job No. V76248 B



* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	During Drilling: (2)(4) W.L.	During Drilling: (5) W.C.	During Drilling: (6) Other	After Drilling: (2)(7) S.W.L.	After Drilling: Permeability D(2)(8)	After Drilling: Permeability K (8)	After Drilling: Permeability M (8)	Comments
Sand, Gravel	0 67 81	1 72					-42				Severe caving conditions 0-T.D.
Clst., Sst., Slst., Congl.		3½"									
	514	540 1 539					-38				Hole "making water" when casing pulled back to 520.
Mixed coal Unit		3"									
Congl., Slst., Sst.	834										
Mixed coal Unit	931										
Slst., Sst., Congl.	1104										
Mixed Coal Unit	1217 1271	T.D.									

Contractor Coates
Date started 22/6/76
Date completed 28/6/76
Logged by DFF
Checked by DEW
Date 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 200 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-137
Sheet 1 of 1

Project: Hat Creek Coal Development

Job No. V76e348-8

Type of Drilling	Rotary Core
Rig	Longyear 38 Wireline
Drilling Fluid	Bentonitic Mud
Coordinates	E 17512 / N 77027
Angle from Horizontal	90°
Bearing	- ° Azimuth
Reference Elevation	3398
Type No.(9)	3
Purpose of Hole	Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	W.L. (2)(4)	W.C. (5)	Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D(2)(8)	K (8)	M (8)	Comments
Gravel, Clay	0 – 43										
Slst., Sst., Congl.	43 – 168	3½"									
Grano. Breccia	168 – 198										
Slst., Sst., Congl.	198 – 320	238, 260; (1) 253					-1				Caving
Mixed Coal Unit	320 – 488										
Coal	488 – 732	3"									
	1242 T.D.										

Contractor: Coates
Date started: 29/6/76
Date completed: 9/7/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 200 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-138
Sheet 1 of 2

Job No. V76348 B

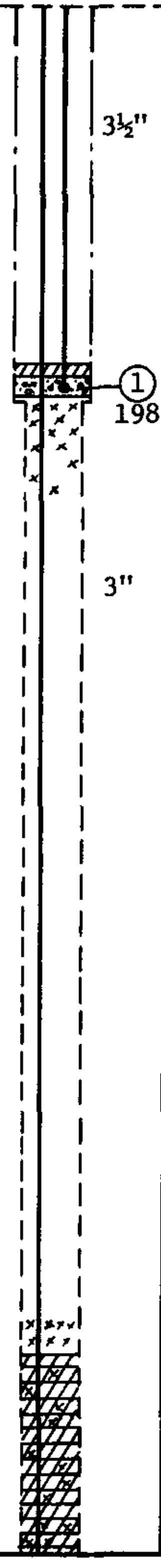
Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates E 19461
N 80977
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3000
Type No.(9) 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	K (8)	M (8)	Comments
	0										
Gravel, Clay		3½"									
	58										
	194										
	202	1 198					-159				
		3"									
Coal											
			680								
	750										Caving
Slst., Sst.											



Contractor: Coates
Date started: 2/7/76
Date completed: 7/7/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 100 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-138
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	After Drilling: Permeability D (2)(8)	After Drilling: Permeability K (8)	After Drilling: Permeability M (8)	Comments
Slst., Sst.	820 827 846	T.D. 1 825					-172				

Vertical scale: 1 in. to 100 ft.

Golder Associates

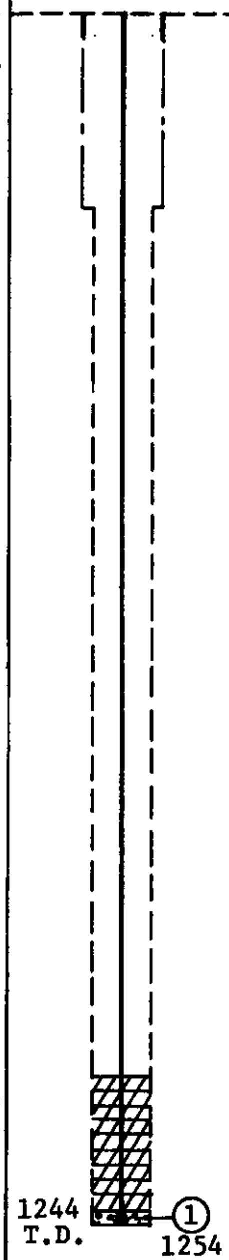
SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-141
Sheet 1 of 1

Project: Hat Creek Coal Development
Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud
Coordinates: E 18517, N 77001
Angle from Horizontal: 90°
Bearing: - ° Azimuth
Reference Elevation: 3342
Type No.(9): 3
Purpose of Hole: Geotechnical Study

Job No. 1762498

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
Sand, Gravel	32										
	62										
Sst., Slst.											Squeezing
	204										
Coal											
	400										
Clst.											
	460										
Coal											
	787										
Slst.											
	925										
Coal											
	1130										
Slst., Sst., Congl.											
	1257	1244 T.D.; (1) 1254					-62				



Contractor: Coates
Date started: 10/7/76
Date completed: 15/7/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 200 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-143
Sheet 1 of 1

Job No. V76238B

Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 38 Wireline
Drilling Fluid Bentonitic Mud

Coordinates E 19028
N 82027
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 2896
Type No.(9) 3
Purpose of Hole Geotechnical Study

* (1) Lithology	(2) Depth	Completed (2)(3) Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
Gravel, Clay	0										
	30										
	32										
Clst.	56										
	80										
Slst., Sst.											
	337										
		1 348					-72				
	351										
	362	T.D.									

Contractor Coates
Date started 15/7/76
Date completed 18/7/76
Logged by RFF
Checked by BEW
Date 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

Job No. V76348 A

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-144
Sheet 1 of 1

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates E 20505
N 76991
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3135
Type No.(9) 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed (2)(3) Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability D(2)(8)	K (8)	M (8)	Comments
	0										
Sand, Gravel		3½"									
	130	138									
Clst.	160										
		3"									
Coal			680								
						*					* Squeezing
			780								
	1074	1084 T.D. 1081 (1)					-59				

Contractor: Coates
Date started: 16/7/76
Date completed: 20/7/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 200 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-146
Sheet 1 of 1

Job No. V76299 B

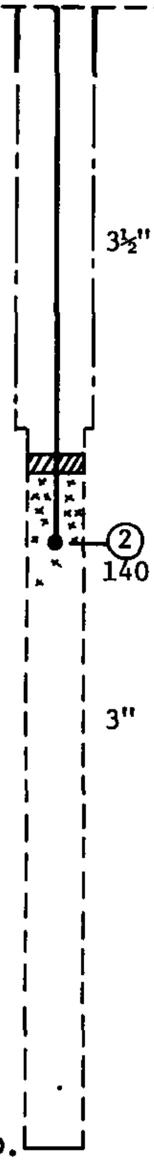
Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates: E 18921, N 81518
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 2857
Type No.[9]: 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	W.L. (2)(4)	W.C. (5)	Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D(2)(8)	K (8)	M (8)	Comments
Gravel	0										
	64	3½"									
Clst., Slst., Sst.	110										
	121										
		② 140					-62				Piezometer lost after 1 month of operation. Reading as of 21/08/76
		3"									
	296	T.D.									



Contractor: Coates
Date started: 18/7/76
Date completed: 20/7/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-148
Sheet 1 of 1

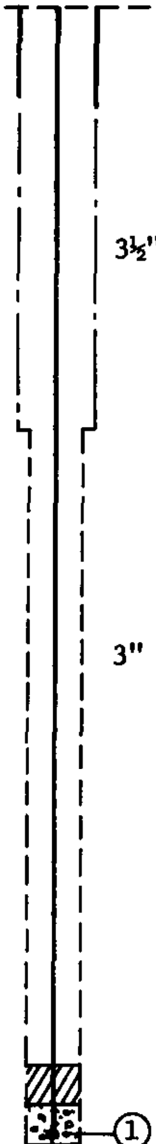
Job No. V76348B

Project: Hat Creek Coal Development
Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates E 17977
N 80521
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 2969
Type No.(9) 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	During Drilling (2)(4) W.L.	During Drilling (5) W.C.	During Drilling (6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	Permeability K (8)	Permeability M (8)	Comments
Gravel, Clay	0										
Clay	57	3½"									
	110	3"									
Clst., Sst., Congl.	231										
	284	① 293					-150				
	295	T.D.									



Contractor: Coates
Date started: 21/7/76
Date completed: 22/7/76
Logged by: DFF
Checked by: DEW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

Job No. K763488

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-149
Sheet 1 of 1

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Natural Mud

Coordinates E: 19003
N: 75981
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 3267
Type No.(9): 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D(2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
	0	3½"									
Gravel, Clay	115	(2) 120					-51				
	177										
Slst.		3"									
	596										
Coal											
	782										
Slst.	827										
Coal											
	1314										
Slst., Sst.	1488	(1) 1506					-81				
	1547 T.D.										

Contractor: Coates
Date started: 22/7/76
Date completed: 28/7/76
Logged by: DFE
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 200 ft.

Job No. V76248 A

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-150
Sheet 1 of 2

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates E 18517
N 81006
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 2891
Type No.(9) 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
Gravel, Clay		3½"									
	100										
	112										
	220	3"									
Clst., Sst., Slst.											

Contractor: Coates
Date started: 23/7/76
Date completed: 24/7/76
Logged by: DFE
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-150
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
	406										
Clst., Sst., Slst.	414	T.D. ① 411					251				

Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-151
Sheet 1 of 1

Job No. V76398 B

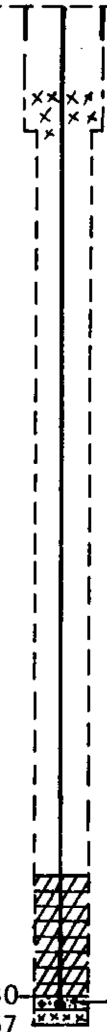
Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates E: 20996
N: 78484
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 3019
Type No.(9): 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
Sand, Gravel	119	3½"									
	130										
Coal		3"									
	1037	1030 (1) 1035					148				
		1057 T.D.									
Sst., Clst.											



Contractor: Coates
Date started: 25/7/76
Date completed: 28/7/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 200 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-152
Sheet 1 of 1

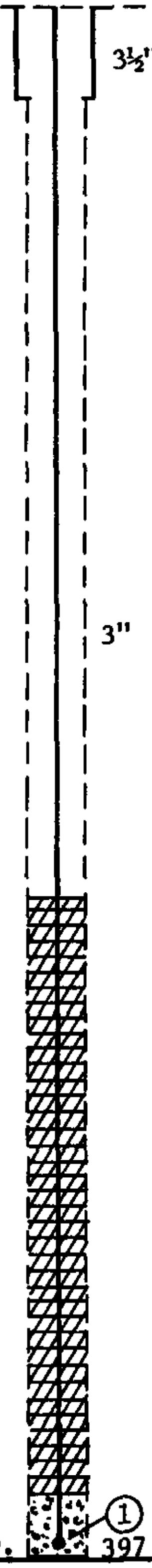
Project: Hat Creek Coal Development
Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates: E 19728; N 82020
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 2822
Type No.(9): 3
Purpose of Hole: Geotechnical Study

Job No. V76348 A

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling: (2) Depth	During Drilling: (2)(4) W.L.	During Drilling: (5) W.C.	During Drilling: (6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
	0										
Sand, Gravel		3½"									
	25										
Coal		3"									
	292										
Clst., Sst.						*					* Squeezing
	383	①									
	400	T.D. 397					-10				



Contractor: Coates
Date started: 25/7/76
Date completed: 26/7/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-155
Sheet 1 of 1

Job No. V76039-A

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates: E 19485, N 77989
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 3167
Type No.(9): 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed (2)(3) Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
Sand, Gravel	82 90	(1) 88 3½"					-61				
	187 200										
Mixed Coal Unit		3"									
Coal	716										
Mixed Coal Unit	773 797	T.D. (1) 790					-46				

Contractor: Coates
Date started: 30/7/76
Date completed: 4/8/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 100 ft.

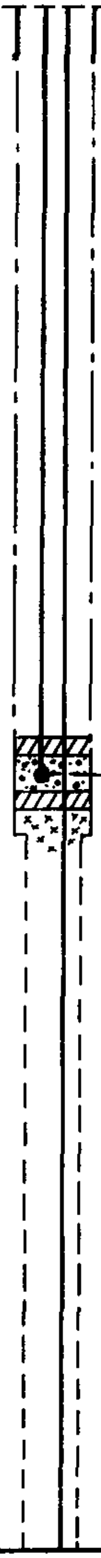
SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-156
Sheet 1 of 2

Project Hat Creek Coal Development
Type of Drilling Rotary Core
Rig Longyear 38 Wireline
Drilling Fluid Bentonitic Mud
Coordinates E 21029
N 81484
Angle from Horizontal 90°
Bearing - ° Azimuth
Reference Elevation 3034
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No. V76348 B

* (1) Lithology	(2) Depth	Completed (2)(3) Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
		3½"									
Sand, Gravel, Clay											
	190										
	204	① 200									No water in piezometer.
	216										
		3"									
Coal											



Contractor Coates
Date started 2/8/76
Date completed 4/8/76
Logged by DFF
Checked by DFW
Date 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-156
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
Coal											
Mixed Coal Unit	483										
Slst., Sst.	514										
	560										
	575	T.D. (1) 573					-162				

Vertical scale: 1 in. to 50 ft.

Golder Associates

Job No. V76239 B

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-158
Sheet 1 of 1

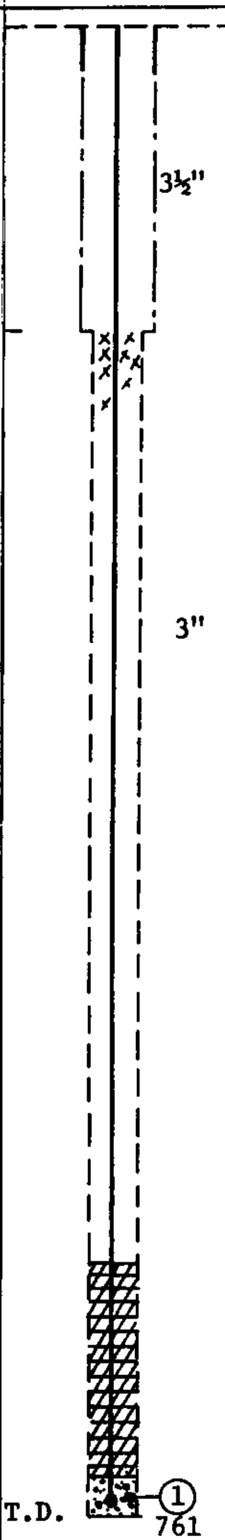
Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates: E 17907, N 79004
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 3217
Type No.(9): 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	During Drilling (2)(4) W.L.	During Drilling (5) W.C.	During Drilling (6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	Permeability K (8)	Permeability M (8)	Comments
Sand, Gravel	0										
Slst.	60	3½"									
Carb. Slst.	123										
	160	3"									
Coal	386		510			LW					
Sst., Slst., Congl.	607										
	752	1 761					185				
	773 T.D.										



Contractor: Coates
Date started: 7/8/76
Date completed: 9/8/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 100 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-160
Sheet 1 of 1

Job No. V76348 B

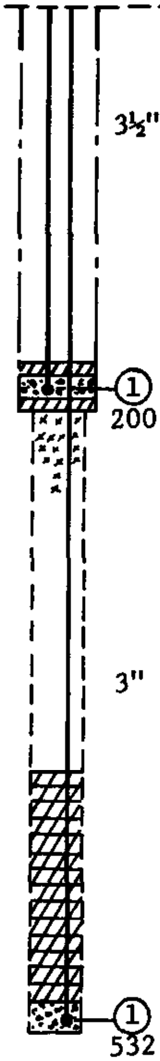
Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 38 Wireline
Drilling Fluid Bentonitic Mud

Coordinates E 21022
N 81999
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3035
Type No.(9) 3
Purpose of Hole Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	W.L. (2)(4)	W.C. (5)	Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0	3½"									
Sand, Gravel	195	①					183				
	205	200									
	238	3"									
Carb. Clst.	474										
	496										
Slst.	519	①					190				
	536 T.D.	532									



Contractor Coates
Date started 9/8/76
Date completed 10/8/76

Logged by DFF
Checked by DFW
Date 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 100 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-161
Sheet 1 of 2

Project: Hat Creek Coal Development

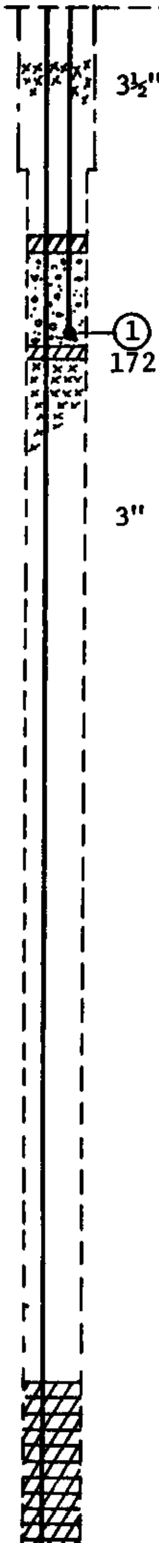
Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates: E 18526, N 80012
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 3132
Type No.(9): 3
Purpose of Hole: Geotechnical Study

Job No. V76398B

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
Gravel, Clay	30	3½"									
	50										
Clst.	124										
	177	1 172					128				
	228										
		3"									
Slst., Sst., Congl., Clst.	707										



Contractor: Coates
Date started: 10/8/76
Date completed: 13/8/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 100 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-161
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W. L. (2)(4)	During Drilling: W. C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
Slst., Sst., Congl., Clst.	817	①					200				
	853	T.D. 842									

Vertical scale: 1 in. to 100 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-163
Sheet 1 of 2

Job No. V7639B B

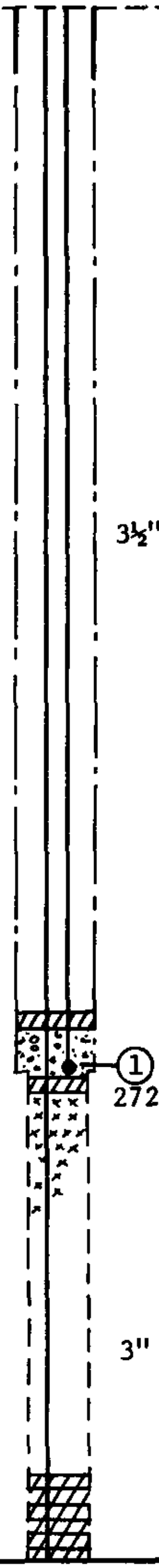
Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates E 21035
N 82501
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3037
Type No.(9) 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D(2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
	0										
Sand, Clay		3½"									
		263									
	270	1					-225				Standpipe blocked. Reading as of 31/08/76.
	276	272									
Coal		3"									



Contractor: Coates
Date started: 11/8/76
Date completed: 13/8/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

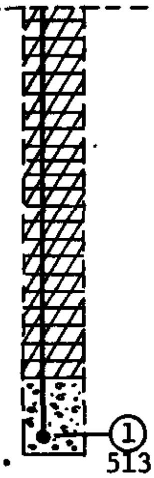
Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-163
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
Coal											
	438										
Clst., Slst., Congl.											
	497										
	516	T.D.					-212				Standpipe blocked. Reading as of 31/08/76.



Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-168
Sheet 1 of 2

Project: Hat Creek Coal Development

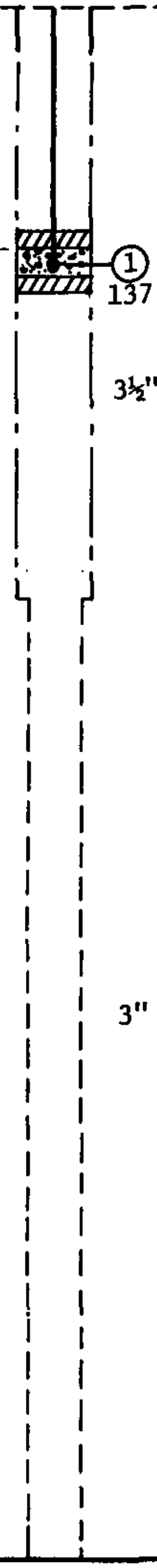
Type of Drilling: Rotary Core
Rig: Longyear 38 Wireline
Drilling Fluid: Bentonitic Mud

Coordinates E 21469
N 79994
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 2941
Type No.(9) 3
Purpose of Hole: Geotechnical Study

Job No. K763498 D

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	K (8)	M (8)	Comments
	0										
Sand, Gravel											
	120	128					108				
	140	137									
Coal											
	766										
Clst., Slst., Congl.											



Contractor: Coates
Date started: 18/8/76
Date completed: 23/8/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 100 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-168
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	After Drilling: Permeability D (2)(8)	After Drilling: Permeability K (8)	After Drilling: Permeability M (8)	Comments
Clst., Slst., Congl.	846	T.D.									

Vertical scale: 1 in. to 100 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-801
Sheet 1 of 2

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates: E 21326, N 73377
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 3228
Type No.(9): 3
Purpose of Hole: Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	During Drilling (2)(4) W.L.	During Drilling (5) W.C.	During Drilling (6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	Permeability K (8)	Permeability M (8)	Comments
	0										
Till											
	52										
	64										
					24						
Sand, Silt											
					25						
	110				21						
		4½"			21						
	140										
					20						
					23						
Till											
			220		10	MW					Mud being diluted.
					35						
					26						
	274										
		3 3/4"									
	330					MW					
Slst., Clst.											
											High water pressure.
	380	395			33						
		1					-99				

Contractor: Tonto
Date started: 4/6/76
Date completed: 14/6/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

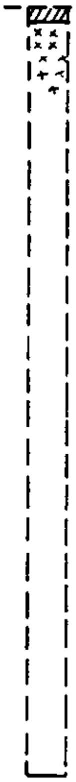
Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-801
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W. L. (2)(4)	During Drilling: W. C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
		398									High water pressure.
Slst.,Clst.											
		3"									
			570	0							
	600	T.D.									



Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-802
Sheet 1 **of** 2

Project Hat Creek Coal Development

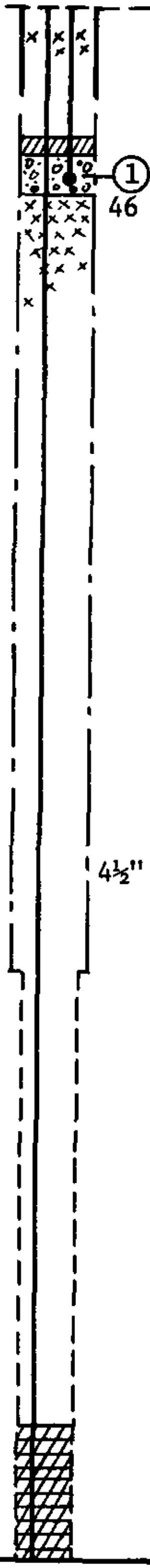
Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 15985
N 73261
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3500
Type No. (9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	K (8)	M (8)	Comments
Till	0										
	9										
					20						
	24				30						
	38				38						
		①					-7				Reading as of 18/07/76.
	49	46			30						
					31						
					40						
					30						
					31						
			125			MW					
Slst., Sst., Congl.		4½"									
	250										
			260			MW					



Contractor Tonto
Date started 6/6/76
Date completed 14/6/76
Logged by DFF
Checked by DFW
Date 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

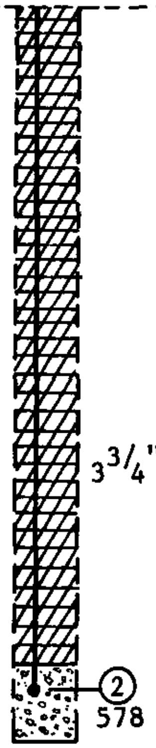
Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-802
Sheet 2 **of** 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
			420			MW					
			465			MW					
Slst., Sst. Congl.											
			490			MW					
		$3^3/_4$"									
											Squeezing
	570					MW					
		2, 578					+11				Standpipe with pneumatic piezometer connected to top.
	590	T.D.									



Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-803
Sheet 1 of 2

Project: Hat Creek Coal Development

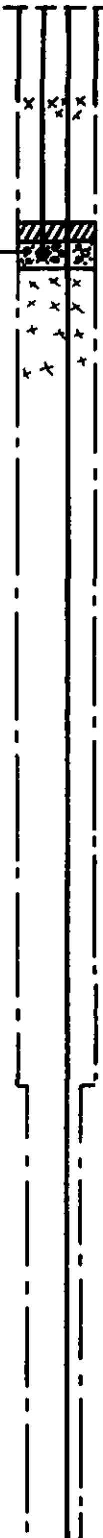
Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates E 20390
N 75190
Angle from Horizontal 75°
Bearing 145 ° Azimuth

Reference Elevation 3169
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	During Drilling (2)(4) W.L.	During Drilling (5) W.C.	During Drilling (6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	Permeability K (8)	Permeability M (8)	Comments
	0										
	25										
Till											
	58	1					-61				
	68	66									
	105										
					34						
					33						
		4½"									
					31						
Clayey Slst.											
	280										
					26						
					14						
					39						
					34						
					27						
					28						



Contractor: Tonto
Date started: 16/6/76
Date completed: 23/6/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-803
Sheet 2 **of** 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
		$3^{3}/_{4}$"			25						
					34						
					12						
	550	①									
	600	552									
Clayey Slst.					36		-21				
	596				30						
					50						
					29						
		3"			31						
					25						
					28						
					32						Squeezing
					30						
					25						
					31						
					29						
					31						
	745	T.D.		-111							

Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

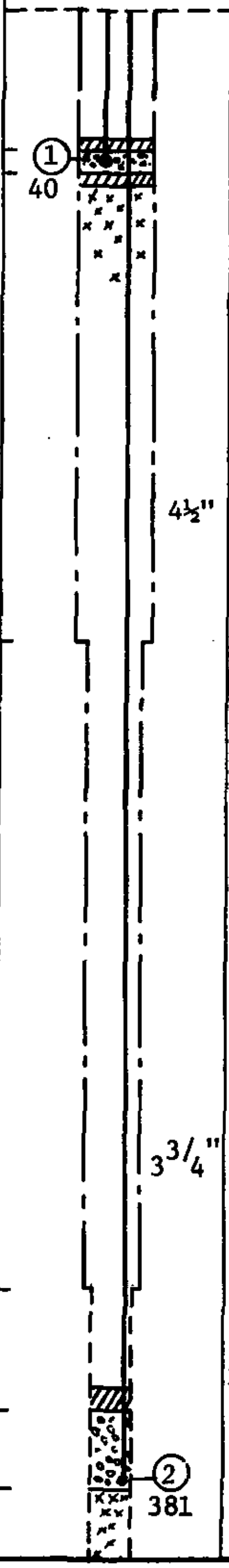
DRILLHOLE No. 76-804
Sheet 1 of 2

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core	Coordinates E 15097	Reference Elevation 3531
Rig: Longyear 44 Wireline	N 75863	Type No.(9) 3
Drilling Fluid: Natural Mud	Angle from Horizontal 90°	Purpose of Hole: Geotechnical Study
	Bearing - ° Azimuth	

Job No.

* (1) Lithology	(2) Depth	Completed (2)(3) Construction	During Drilling (2) Depth	During Drilling (2)(4) W.L.	During Drilling (5) W.C.	During Drilling (6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	Permeability K (8)	Permeability M (8)	Comments
Till	0										
	35	①					-27				
	45	40									
Slst. Breccia			65		50	LW					Caving
Sst.	111		106			LW					Squeezing
	123	4½"									
	165				14						
			225		24	LW					Caving
Slst., Sst., Congl.					44						
		$3^{3}/_{4}$"			12						
					18						
					20						
					26						
	330										
					12						
			350		12						
	361				27						
	382	② 381				MW					Piezometer not operational.
					34						



Contractor: Tonto	Logged by: DFF	* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.
Date started: 16/6/76	Checked by: DEW	Golder Associates
Date completed: 23/6/76	Date: 14/2/77	Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-804
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
Slst., Sst., Congl.		3"			29 17 18	MW					
	437	T.D.									

Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-805
Sheet 1 of 1

Project Hat Creek Coal Development

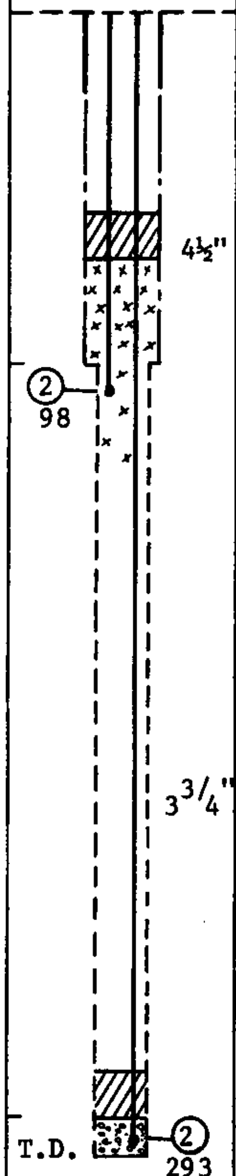
Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 14429
N 79253
Angle from Horizontal 75°
Bearing 270 ° Azimuth

Reference Elevation 3363
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling: (2) Depth	During Drilling: (2)(4) W.L.	During Drilling: (5) W.C.	During Drilling: (6) Other	After Drilling: (2)(7) S.W.L.	After Drilling: Permeability D(2)(8)	After Drilling: Permeability K (8)	After Drilling: Permeability M (8)	Comments
Till	0										
	12										
Sst.											
	59	4½"			26						
Sheared, Clayey Sst/Slst.					42						
					17						Caving
	81				21						
Sst.	90										
	100	2 98			48		-6				
					27						
					26						
			145	-43							
					13						Squeezing
			162	-55							
					12						
Slst., Sst. Congl.		3 3/4"	206	-38							
	287										
	295	T.D. 2 293	295	-45			-18				



Contractor Tonto
Date started 26/6/76
Date completed 29/6/76
Logged by DFF
Checked by DWF
Date 2/4/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-806
Sheet 1 **of** 2

Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 16108 N 79182
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3377
Type No. (9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	During Drilling: (2)(4) W.L.	During Drilling: (5) W.C.	During Drilling: (6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
Till	0 16										
		4½"	25		31						
					52						
	60	2 59			28		-20				
					38						
					79						
					33						
					32						
					58						Hole making water between shifts 77-225.
						LW					
					32						
					34						
					34						
					31						
					53						
					31						
		$3^{3}/_{4}$"									
Clayey Slst. (Sst., Congl.)			225								
					33						
					31						
					28						
					20						
	280										
					23						
					24						
					26						
					30						
					25						
					31						
					20						
		3"									
					37						
					29						
			400	0	32						

Contractor Tonto **Logged by** DFF
Date started 25/6/76 **Checked by** DFW
Date completed 6/7/76 **Date** 2/14/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-806
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	W.L. (2)(4)	W.C. (5)	Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	K (8)	M (8)	Comments
					30						
					26						
					27						
Clayey Slst. (Sst., Congl.)	454				31						
	468	1 466	465	0	26		-35				
					30						
					28						
					27						
					36						
	542				35						
					33						
			593	0							
					26						
					31						
			645	0	32						
Congl., (Slst.,Sst.)					35						
	721	T.D.		0							

Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-807
Sheet 1 of 1

Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 12426
N 78106
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3558
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling Depth (2)	During Drilling W.L. (2)(4)	During Drilling W.C. (5)	During Drilling Other (6)	After Drilling S.W.L. (2)(7)	Permeability D(2)(8)	Permeability K (8)	Permeability M (8)	Comments
	0										
					20						
Sand, Till, Sheared Material	27	4½"			27						
						MW					
			40	-15							
					26						
					33						
	70		70	-5							
						MW					
			80	-30							
	83										
Clayey Slst., Sst.			90	-5							
		$3^3/_4$"			17						
					21						
Clay, Silt, Coal	120				25						Sheared zone 114-135.
	145				13						
					24						
					17						
Sst.			180	0							
	197										
	209	T.D. (2) 205					-44				

Contractor Tonto
Date started 6/7/76
Date completed 10/7/76
Logged by DFF
Checked by DFW
Date 2/14/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-808
Sheet 1 of 2

Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 17612
N 81317
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3084
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling Depth (2)	During Drilling W.L. (2)(4)	During Drilling W.C. (5)	During Drilling Other (6)	After Drilling S.W.L. (2)(7)	Permeability D(2)(8)	Permeability K (8)	Permeability M (8)	Comments
Sheared Bentonite	0	4½"									
	10				32						
	40				40						
	47				40						
Slst.			55	-10							
					31						
					34	LW					
			105	-22							
		3 3/4"			22						
					27						
			154	-10	20						
					8						
			187	-5	24						
					34						
					31						
					30						
					32						
					21						
			257	-5							
					27						
					26						
					26						
			304	-4							
					16						
					26						
			328	-33	38						
					28						
					30						
					30						
					31						
			395	0							

Contractor Tonto
Date started 12/7/76
Date completed 20/7/76
Logged by DFF
Checked by DFW
Date 2/14/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-808
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: Q (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
					31						
					36						
					30						
					32						
Slst.					32						
					43						
					25						
			540	-10							
					34						
	561				30						
	574	T.D. 1 570			83		-186				

Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-809
Sheet 1 of 2

Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 17230
N 82036
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3079
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	During Drilling (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	K (8)	M (8)	Comments
Sand, Gravel	0									
	15			32						
				42						
Sheared Bentonite	35				LW	-22				
		50	0							
				38						
	64									
				27						
				31						
		95	0							
				34						
Slst.				31						
		160	-6	46						
				36						
				38						
	205	205	0							
				19						
				30						
				36						
				17						
		270	-11							
				25						
				31						
				24						
Congl., (Slst., Sst.)				30						
		330	0							
				34						
		370	0							
				30						
				20						

Contractor Tonto
Date started 22/7/76
Date completed 27/7/76

Logged by DFF
Checked by DFW
Date 2/14/77

*** NOTE**: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-809
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
			406	0							
			429	0							
					25						
	459	–									
		1			28		-62				
	474	T.D. 470									

Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-810
Sheet 1 of 1

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates: E 16337, N 83287
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 3024
Type No.(9): 3
Purpose of Hole: Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	After Drilling: Permeability D (2)(8)	After Drilling: Permeability K (8)	After Drilling: Permeability M (8)	Comments
	0										
	45										
			60	-12	25	LW					
					46						
Sand, Gravel, Till			120			LW					
		4½"	185	-25							
	217										
			220	-25							
Sheared Slst.					37						
	277			-43		LW					
	292										
Congl.	300	2 299									Piezometer not operational.
	314										Squeezing.
Sst.											
	329	3 3/4"									
Gravel, Congl.						MW					
	354	T.D.									

Contractor: Tonto
Date started: 3/8/76
Date completed: 10/8/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-811
Sheet 1 **of** 1

Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 18100 N 82543
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 2949
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	During Drilling: (2)(4) W.L.	During Drilling: (5) W.C.	During Drilling: (6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
Sand, Gravel	0	4½"									
Bentonite	13										
	20					LW					
Slst.					34						
					29						
					31						
					37						
	107										
Slst., Sst.			120	0							
					36						
		$3^3/4$"									
	147										
Congl.	155										
Slst.	167				38						
Congl.			190	0							
	200										
					26						
					38						
					27						
Slst., Congl			290	-14							
					24						
					33						
			365	0							
	381	1									
	398 T.D.	395					-31				

Contractor Tonto
Date started 16/8/76
Date completed 18/8/76
Logged by DFF
Checked by DFW
Date 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-812
Sheet 1 **of** 1

Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 19028
N 82998
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 2823
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	During Drilling: (2)(4) W.L.	During Drilling: (5) W.C.	During Drilling: (6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
	0	4½"	10	0							
Till											
					43						
	46				34						
					34						
Slst., Sst., Congl.											
	85				29						
					30						
					30						
Carb. Slst.											
					35						
		3 3/4"									
					30	LW					
	180				31						
			215	-5							
					32						Caving
					31						
	250			-13							
					33						
Slst.,Sst., Congl.											
					24						
			290	0							
		3"									
					28						
	317										
		1					-15				
	330	325			27						
					27						
			350	-5							
					27						
					28						
	398 T.D.										

Contractor Tonto
Date started 24/8/76
Date completed 28/8/76
Logged by DFF
Checked by DFW
Date 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-813
Sheet 1 **of** 2

Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 19058
N 84552
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 2881
Type No. (9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	K (8)	M (8)	Comments
	0	4½"									
	20		15	-2							
			130	0							
		3 3/4"									
Till											
			235	0							
			365	0							
			367	-31							
	373	①					-128				
	387	382	395	-14							

Contractor Tonto
Date started 15/8/76
Date completed 22/8/76
Logged by DFF
Checked by DFW
Date 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-813
Sheet 2 **of** 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
			440	-133							
Till											
			490	-3							
	518		520	-43	29						
					28						
					28						
Clayey Slst.					32						
	580	3"									
			585	-4	29						
Slst., Sst., Congl.											
	609										
					23						
Slst., (Sst.)			630	0	31						
					27						Caving
	655	T.D.				LW					Squeezing

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-814
Sheet 1 of 2

Project: Hat Creek Coal Development
Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud
Coordinates: E 20041, N 83506
Angle from Horizontal: 90°
Bearing: - ° Azimuth
Reference Elevation: 2970
Type No.(9): 3
Purpose of Hole: Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	K (8)	M (8)	Comments
	0										
		4½"									
			125	-11							
Till	180										
			195	-52							
		3 3/4"									
			290	-12							
	328										
	336	1 332					-176				
	341		350	-14	24						
			360	-28	33						
			370	-7							
Slst.,Clst.					36						
					30						
	400										

Contractor: Tonto
Date started: 8/8/76
Date completed: 13/8/76
Logged by: DFF
Checked by: DEW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

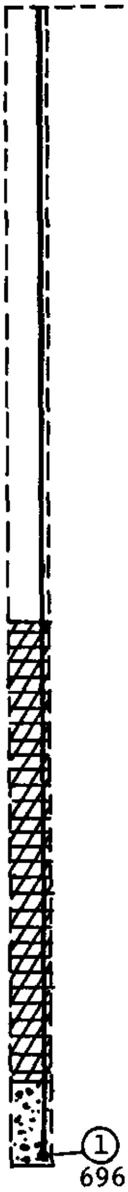
Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-814
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
					26						Caving
			415	-4							
					24						
			435		33						
					31						
					32						
			470	-8	20						
	485				32						
			500	0	26						
					24						
					25						
			550	-11							
					26						
Slst., Coal					25						
					25						
					24						
			620	-6	23						
					23						
	645				27						
Slst., Sst., Coal	679										
		1 696		-12			-48				
	700	T.D.									



Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-815
Sheet 1 of 2

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates E 23489
N 78982
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3150
Type No.(9) 3
Purpose of Hole: Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
			55	0							
		4½"	105	0							
	140	xxx xxx									
			175	0							
	190										
Sand, Gravel, Till			200	-140							
		3 3/4"	230	-35							
	260										
					34						
					34						
		3"									
			315	-2							
			350	-87							
			400	-88							

Contractor: Tonto
Date started: 8/7/76
Date completed: 16/7/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-815
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	W.L. (2)(4)	W.C. (5)	Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	K (8)	M (8)	Comments
	402				30						
					37						
					35						
					20						
					33						
					17						
			455	-63							
					33						
					40						
					28						
					34						
					29						
					31						
			515	-45							
					34						
					30						
					19						
Clayey Slst.					30						
					35						
					29						
			585	-24	11						
						LW					Squeezing
	609				33						
	624	1 621			33		-305				
					35						
			645	-20	30						
					35						
	673 T.D.			-68							

Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-816
Sheet 1 of 3

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates: E 24624, N 78956
Angle from Horizontal: 75°
Bearing: - ° Azimuth

Reference Elevation: 3249
Type No.[9]: 3
Purpose of Hole: Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	During Drilling (2)(4) W.L.	During Drilling (5) W.C.	During Drilling (6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	Permeability K (8)	Permeability M (8)	Comments
	0										
			50	-2							
	132										
Sand, Gravel, Till		4½"	155	-2							
	250			-104							
			270	-40							
			290	-20	20						
		3 3/4"			30						
	312										
	326	1 327			37		-152				
	338		340	-10	29						
					25						
					25						
Clayey Slst.					27						
					23						
			390	-7							

Contractor: Tonto
Date started: 18/7/76
Date completed: 28/7/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

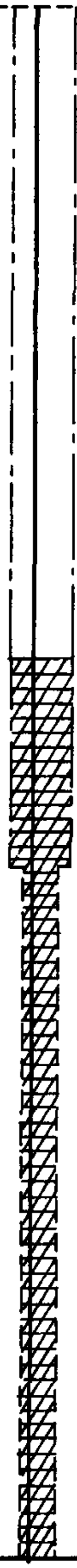
Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-816
Sheet 2 of 3

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	W.L. (2)(4)	W.C. (5)	Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	K (8)	M (8)	Comments
					22						
					31						
Clayey Slst.			430	-136							
					24						
					30						
					28						
					32						
	499		500	-154							
			590	-158							
Congl.											
	650		650	-33							
		3"									
	751		750	-9							
Congl., (Sst.)											
	776										
Basalt			815	-4							



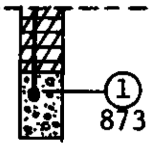
Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-816
Sheet 3 of 3

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: Q (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
	867										
Basalt		1 873	875	-31			-215				
	884	T.D.									

Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-817
Sheet 1 **of** 2

Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 19985 N 81496
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 2836
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D(2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
	0	4½"									
	20										
Alluvium	33										
	60										
					41						
			100	-15	39						
		3 3/4"			41						
					42						
					46						
					36						
					36						
					36						
					37						
					35						
					42						
					30						
Coal					37						
					28						
					30						
					38						
					31						294
					33						
					45						
			350	-15							
					37						Drilling with water.
					44						

Contractor Tonto
Date started 21/8/76
Date completed 27/8/76
Logged by DFF
Checked by DFW
Date 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

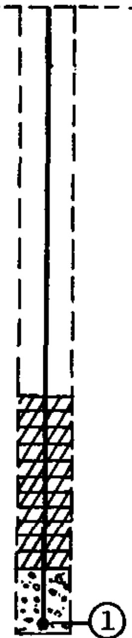
Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. 76-817
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
Coal					39						Drilling with water. 444
Silty Coal	441		445	-17							
	464				22						
Clayey Slst/ Sst.			500	-20							
	545										
	561	T.D. 1 555					-30				



Vertical scale: 1 in. to 50 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-818
Sheet 1 of 1.

Project Hat Creek Coal Development

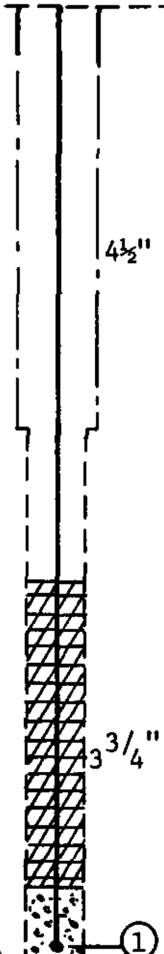
Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 15552
N 82788
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3182
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	During Drilling (2)(4) W.L.	During Drilling (5) W.C.	During Drilling (6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	Permeability K (8)	Permeability M (8)	Comments
	0										
					39						
					49						
					33						
		4½"									
			70	-27							
					28						
											Squeezing, "sand" in hole.
	110			-7							
Slst., Sst., Congl.											
			160	0							
					24						
		3 3/4"									
					38						
	229										
	247 T.D.	1 244		0			~150				



Contractor Tonto
Date started 12/8/76
Date completed 14/8/76
Logged by DFF
Checked by DFW
Date 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-819
Sheet 1 of 1

Project Hat Creek Coal Development

Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 15716
N 83733
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 2930
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
	0	4½"									
	20										
			35	0							
			80	-15							
Sand, Gravel, Till		3 3/4"									
			150	-34							Hole uncased when W.L. reading taken.
	164										
											High mud pressure.
	214										
	224	(2) 222					-111				
	246										
			265			MW					
Slst., Sst.		3"									
	319	T.D.									

Contractor Tonto
Date started 29/8/76
Date completed 2/9/76
Logged by DFF
Checked by DFW
Date 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-820
Sheet 1 of 1

Project: Hat Creek Coal Development

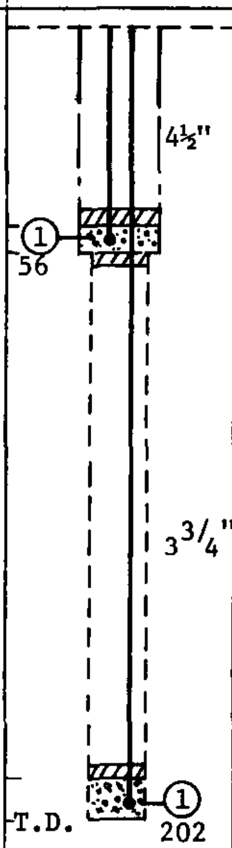
Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates E 22872
N 69184
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3084
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling (2) Depth	During Drilling (2)(4) W.L.	During Drilling (5) W.C.	During Drilling (6) Other	After Drilling (2)(7) S.W.L.	Permeability D(2)(8)	Permeability K (8)	Permeability M (8)	Comments
Sand, Gravel	0										
	28	4½"	35	70	39						
Clayey Slst.					57						
	52						-8				"Sand" in hole.
	59	56			38						
					37						
					37	MW					"Sand" in hole.
					51						
					27						
					25						
		$3^3/_4$"			35						
					40						
					29						
					35						
					11						
					14						
	195				27		-6				
	207	T.D. 202									



Contractor: Tonto
Logged by: DFF
Date started: 10/9/76
Checked by: DFW
Date completed: 13/9/76
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-821
Sheet 1 of 1

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates E 22929
N 75507
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 2963
Type No.(9) 3
Purpose of Hole: Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
Sand, Gravel, Till		6"									
	65										
			70	-7							
			125	-2							
Brecciated Slst.		3"									
	227										
		1 234					-8				
	239	T.D.									

Contractor: Tonto
Date started: 14/9/76
Date completed: 16/9/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-822
Sheet 1 of 1

Job No.

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates E: 38465
N: 76868
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 3943
Type No.(9): 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	During Drilling: (2)(4) W.L.	During Drilling: (5) W.C.	During Drilling: (6) Other	After Drilling: (2)(7) S.W.L.	After Drilling: Permeability D(2)(8)	After Drilling: Permeability K (8)	After Drilling: Permeability M (8)	Comments
	0										
			30	-4							
Till		4½"	45			MW					
	88	85		-57							
		$3^{3/4}$"	100	-10				80-148	$1.3x10^{-6}$	f.	Caving Test through open hole.
Greenstone	123	①						122-148	$2.4x10^{-7}$	f.	Test through piezometer.
	149	140					Dry				
	170	T.D.									Packer blew & lost in hole - caved in mat'l all around it.

Contractor: Tonto
Date started: 18/9/76
Date completed: 21/9/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-823
Sheet 1 of 1

Project: Hat Creek Coal Development

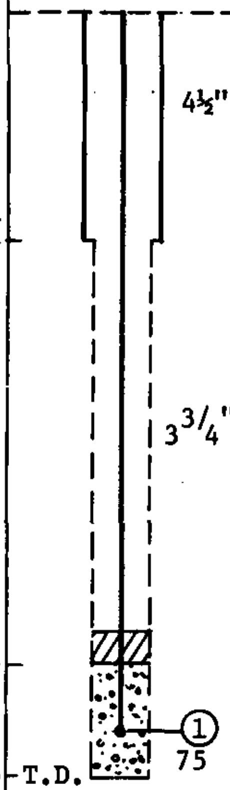
Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates E 38532
N 76506
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3945
Type No.(9) 3
Purpose of Hole: Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	During Drilling: (2)(4) W.L.	During Drilling: (5) W.C.	During Drilling: (6) Other	After Drilling: (2)(7) S.W.L.	After Drilling: Permeability D(2)(8)	After Drilling: Permeability K (8)	After Drilling: Permeability M (8)	Comments
	0										
Gravel											
	21										
	24										
Greenstone											
								40-80	1.8x 10^{-5}	f.	Test through open hole.
	66										
							-12				
	80 T.D.										



Contractor: Tonto
Date started: 22/9/76
Date completed: 23/9/76
Logged by: DFF
Checked by: DEW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 20 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-824
Sheet 1 of 1

Project Hat Creek Coal Development

Type of Drilling Diamond
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 38493
N 76601
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3853
Type No.(9) 3
Purpose of Hole Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	After Drilling: Permeability D (2)(8)	After Drilling: Permeability K (8)	After Drilling: Permeability M (8)	Comments
	0	4½"									
Till			75	-75							No water encountered in the till.
		3 3/4"	115	-115							
			145	-65							
	150										2 cave-ins - 1st to 192' 2nd to 150' after piezo installation & retrieval of HQ rods.
Greenstone		1 169					-155	160-192	3.6x 10-8	f	
	182	3"						160-192	4.0x 10-6	p	
	205	T.D.									170-205' interval subsequently caved in.

Contractor Tonto
Date started 25/9/76
Date completed 4/10/76
Logged by DFF
Checked by DFW
Date 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-825
Sheet 1 of 1

Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates: E 36136, N 82508
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 4600
Type No.(9): 3
Purpose of Hole: Geotechnical Study

Job No.

* (1) Lithology	(2) Depth	Completed (2)(3) Construction	During Drilling (2) Depth	During Drilling (2)(4) W.L.	During Drilling (5) W.C.	During Drilling (6) Other	After Drilling (2)(7) S.W.L.	After Drilling Permeability D(2)(8)	After Drilling Permeability K (8)	After Drilling Permeability M (8)	Comments
Sand	0	4½"									
	20										
Chert	35	3 3/4"					-12				
	50	T.D. 1 45									

Contractor: Tonto
Date started: 6/10/76
Date completed: 7/10/76
Logged by: DFF
Checked by: DEW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 20 ft.

Job No. V76348 B

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-826
Sheet 1 of 1

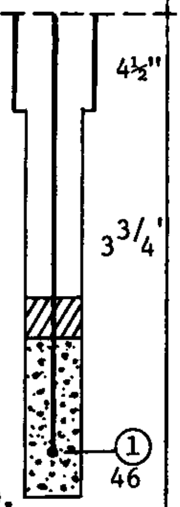
Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates: E 36754, N 82611
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 4619
Type No.(9): 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
	0										
	10	4½"									
Phyllite		3 3/4"									
	34										
		1					-13				
		46									
	50 T.D.										



Contractor: Tonto
Date started: 8/10/76
Date completed: 8/10/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 10 ft.

SUMMARY HYDROLOGIC LOG

Job No. K763483

DRILLHOLE No. 76-827
Sheet 1 **of** 1

Project Hat Creek Coal Development
Type of Drilling Rotary Core
Rig Longyear 44 Wireline
Drilling Fluid Natural Mud

Coordinates E 37163
N 82798
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 4603
Type No.(9) 3
Purpose of Hole Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	After Drilling: Permeability D(2)(8)	After Drilling: Permeability K (8)	After Drilling: Permeability M (8)	Comments
	0										
		4½"									
Till	15										
	24										
	30										
	36	3 3/4"									
	43										
Phyllite											
		1					-12				
	58	T.D. 55									

Contractor Tonto **Logged by** DFF
Date started 9/10/76 **Checked by** DFW
Date completed 10/10/76 **Date** 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 20 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. 76-828
Sheet 1 of 1

Job No. V76248 B

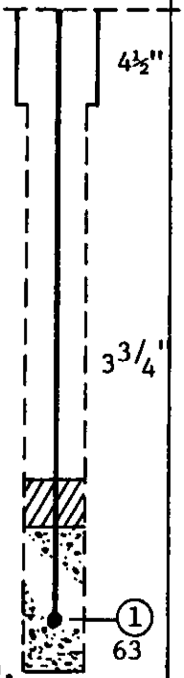
Project: Hat Creek Coal Development

Type of Drilling: Rotary Core
Rig: Longyear 44 Wireline
Drilling Fluid: Natural Mud

Coordinates: E 37301, N 82231
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 4613
Type No.(9): 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed (2)(3) Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
	10										
Sand, Gravel											
	39										
	48										
Phyllite	54										
							-11				
	68	T.D.									



Contractor: Tonto
Date started: 11/10/76
Date completed: 12/10/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 20 ft.

Job No. V76348 B

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. RH-76-10
Sheet 1 of 2

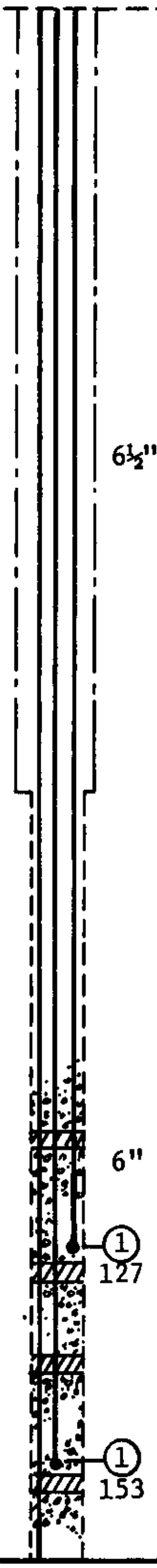
Project Hat Creek Coal Development

Type of Drilling Rotary
Rig Bucyrus Erie
Drilling Fluid Air

Coordinates E 18008
N 76011
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3335
Type No.(9) 3
Purpose of Hole Geotechnical Study

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
Sand, Gravel		6½"									
	81										
Clst.											
	110										
	119	6"									
Carb. Clst.		(1) 127					-82	119 -130	3.2x 10^{-9}	f	
	130										
	136										
	141										
Slst., Sst.		(1) 153					-71	141 -156	5.3x 10^{-9}	f	
	154										
Slst.											



Contractor Tonto
Date started 7/8/76
Date completed 8/8/76

Logged by DFF
Checked by DFW
Date 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

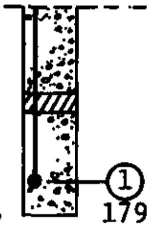
Golder Associates

Vertical scale: 1 in. to 20 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. RH-76-10
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
	163										
Congl.											
	170										
Sst.											
	179	1					-26	172-182	6.0×10^{-9}	f	
Slst., Sst.	182	T.D. 179									

Vertical scale: 1 in. to 20 ft.

Golder Associates

Job No. V76398 B

SUMMARY HYDROLOGIC LOG

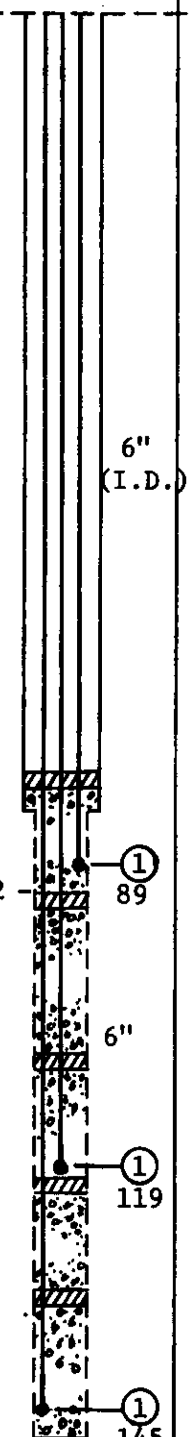
DRILLHOLE No. RH-76-11
Sheet 1 of 1

Project: Hat Creek Coal Development

Type of Drilling: Rotary
Rig: Bucyrus Erie
Drilling Fluid: Air

Coordinates: E 17528, N 76983
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 3397
Type No.(9): 3
Purpose of Hole: Geotechnical Study



* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	During Drilling: (2)(4) W.L.	During Drilling: (5) W.C.	During Drilling: (6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
Bentonite	0										
Basalt	38					MW					
	81										
Bentonite	90						-65	134-148	1.8x10-4	f	
Sst.	110						-61	110-122	4.1x10-9	f	
	122										
Slst., Sst.	125										
	134						-57	81-92	5.7x10-9	f	
	148 T.D.										

Contractor: Tonto
Date started: 9/8/76
Date completed: 10/8/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 20 ft.

Job No. V76348 B

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. RH-76-12
Sheet 1 of 2

Project: Hat Creek Coal Development
Type of Drilling: Rotary
Rig: Bucyrus Erie
Drilling Fluid: Air

Coordinates: E 18490, N 77016
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 3341
Type No.(9): 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
Gravel, Till		6½"									
	62										
Basalt											
	72										
Till											
	76										
	100	6"									
	102										
Sst.		1					-45				
	114	111									
	127										
		1					-53				
	137	134									
	146										
Slst.	154										

Contractor: Tonto
Date started: 8/8/76
Date completed: 9/8/76
Logged by: DFF
Checked by: DEW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 20 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. RH-76-12
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
Slst.		 1									
							-139		1.2×10^{-8}	f	
	174	T.D. 171									

Vertical scale: 1 in. to 20 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. RH-76-13
Sheet 1 of 1

Job No. V76348B

Project	Hat Creek Coal Development		
Type of Drilling	Rotary	Coordinates	E 17000
Rig	Bucyrus Erie		N 78002
Drilling Fluid	Air	Angle from Horizontal	90°
		Bearing	- ° Azimuth

Reference Elevation 3427
Type No.(9) 3
Purpose of Hole Geotechnical Study

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
Bentonite	0	6½"									
Clay, Slst.	42	6"									
Slst.	56, 62										
	77	① 81					-71		2.1×10^{-8}	f	
Slst., Congl	84	85									
	101	① 98					-77		9.5×10^{-9}	f	
	111										
	121 T.D.	① 118					-75		1.4×10^{-8}	f	

Contractor	Tonto	Logged by	DFF
Date started	11/8/76	Checked by	DFW
Date completed	12/8/76	Date	14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 20 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. RH-76-14
Sheet 1 of 1

Job No. V76249 B

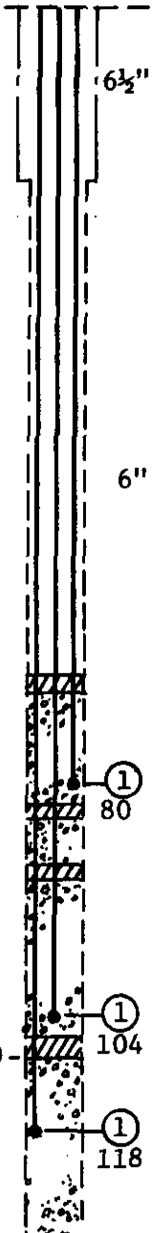
Project: Hat Creek Coal Development

Type of Drilling: Rotary
Rig: Bucyrus Erie
Drilling Fluid: Air

Coordinates E 17227
N 82021
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3083
Type No.(9) 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D(2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
Sand, Gravel	0	6½"									
Bentonite and slide material	15	6"									
Clayey Slst.	64										
	71										
	83	① 80					-61		1.8x 10^{-9}	f	
	91										
	107	109- ① 104					-92		1.9x 10^{-9}	f	
		① 118					-120		3.0x 10^{-9}	f	
	128	T.D.									



Contractor: Tonto
Date started: 13/8/76
Date completed: 13/8/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 20 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. RH-76-15
Sheet 1 of 2

Job No. V76348 B

Project: Hat Creek Coal Development
Type of Drilling: Rotary
Rig: Bucyrus Erie
Drilling Fluid: Air
Coordinates: E 19755, N 82009
Angle from Horizontal: 90°
Bearing: - ° Azimuth
Reference Elevation: 2823
Type No.(9): 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
Sand, Gravel		6½"									
	25										
Coal		6"									
	110						-14	110-123	1.5x10^{-4}	f	
	123	① 120									
	136						-14	136-149	5.8x10^{-5}	f	
	149	① 146									

Contractor: Tonto
Date started: 18/8/76
Date completed: 20/8/76
Logged by: DFF
Checked by: DEW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 20 ft.

SUMMARY HYDROLOGIC LOG (Continued)

DRILLHOLE No. RH-76-15
Sheet 2 of 2

Job No.

Lithology (1)	Depth (2)	Completed Construction (2) (3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
	164						-14	164-149	7.8x10^{-5}	f	
		1 172									
	175										
Coal											
	191						-14	191-202	2.7x10^{-5}	f	
		1 200									
	202	T.D.									

Vertical scale: 1 in. to 20 ft.

Golder Associates

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. RH-76-16
Sheet 1 of 1

Job No. V76248 B

Project: Hat Creek Coal Development

Type of Drilling: Rotary
Rig: Bucyrus Erie
Drilling Fluid: Air

Coordinates: E 19885, N 76552
Angle from Horizontal: 90°
Bearing: - ° Azimuth

Reference Elevation: 3182
Type No.(9): 3
Purpose of Hole: Geotechnical Study

* (1) Lithology	(2) Depth	(2)(3) Completed Construction	During Drilling: (2) Depth	During Drilling: (2)(4) W.L.	During Drilling: (5) W.C.	During Drilling: (6) Other	After Drilling: (2)(7) S.W.L.	After Drilling: Permeability D(2)(8)	After Drilling: Permeability K (8)	After Drilling: Permeability M (8)	Comments
	0										
Till		6½"	60 80			Blowing 25 gpm					
Sand, Silt, Clay	90										
	115										
	150 160	(2) 158					-55				Reading prior to pumping test.
	208 218										Piezometer lost
Clayey Slst.		6"									
	311 318										Piezometer lost
	404	T.D.									

Contractor: Tonto
Date started: 19/8/76
Date completed: 21/8/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

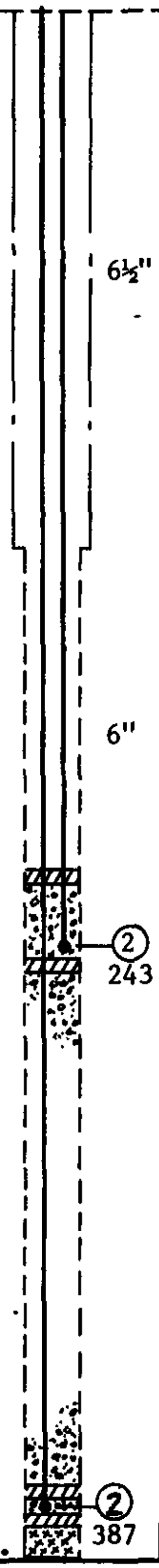
SUMMARY HYDROLOGIC LOG

DRILLHOLE No. RH-76-16A
Sheet 1 of 1

Job No. V76238 B

Project	Hat Creek Coal Development		
Type of Drilling	Rotary	Coordinates	E 19879 / N 76561
Rig	Bucyrus Erie	Angle from Horizontal	90°
Drilling Fluid	Air	Bearing	– ° Azimuth
Reference Elevation	3182	Type No.(9)	3
Purpose of Hole	Geotechnical Study		

* (1) Lithology	(2) Depth	Completed (2)(3) Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
	0										
Till			60			Blowing 25 gpm					
		6½"	80								
Sand, Silt, Clay	90										
	115										
		6"									
	227										
Clayey Slst.	247	(2) 243					-18				Reading prior to pumping test.
	385	-389 (2) 387					-40				Reading prior to pumping test.
	404	T.D.									



Contractor Tonto Logged by DFF
Date started 21/8/76 Checked by DFW
Date completed 22/8/76 Date 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. RH-76-17
Sheet 1 **of** 1

Job No. V76048 B

Project Hat Creek Coal Development

Type of Drilling Rotary
Rig Bucyrus Erie
Drilling Fluid Air

Coordinates E 20145
N 76312
Angle from Horizontal 90°
Bearing - ° **Azimuth**

Reference Elevation 3172
Type No.(9) 3
Purpose of Hole Geotechnical Study

* (1) Lithology	(2) Depth	Completed (2)(3) Construction	During Drilling: (2) Depth	(2)(4) W.L.	(5) W.C.	(6) Other	After Drilling: (2)(7) S.W.L.	Permeability: D(2)(8)	K (8)	M (8)	Comments
Sand	0										
Till	30										
Clayey Slst.	85	6" I.D.									
	157										
	166	② 165					-56				Reading prior to pumping test.
		6"									
	270										
	281	② 279					-42				Reading prior to pumping test.
	391	② 403					-46				Reading prior to pumping test.
	T.D. 404										

Contractor Tonto
Date started 23/8/76
Date completed 24/8/76
Logged by DFF
Checked by DFW
Date 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. RH-76-18
Sheet 1 **of** 1

Job No. V-76348 B

Project Hat Creek Coal Development

Type of Drilling Rotary
Rig Bucyrus Erie
Drilling Fluid Air

Coordinates E 19710
N 76733
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3194
Type No. (9) 3
Purpose of Hole Geotechnical Study

* (1) Lithology	(2) Depth m.	Completed Construction (2)(3)	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	Permeability: K (8)	Permeability: M (8)	Comments
Till	0										
Sand, Silt	70	6" I.D.	80 90			*					*Blowing 50 gpm while drilling.
Till	110										
Clayey Slst.	150										
	160										
	183 193	2 190					-16				Reading prior to pumping test.
	282 285	2 291					-27				Reading prior to pumping test.
	388 400	T.D. 2 392					-35				Reading prior to pumping test.

Contractor Tonto
Date started 24/8/76
Date completed 25/8/76
Logged by DFF
Checked by DFW
Date 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft

Job No. V-76348 B

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. RH-76-19
Sheet 1 of 1

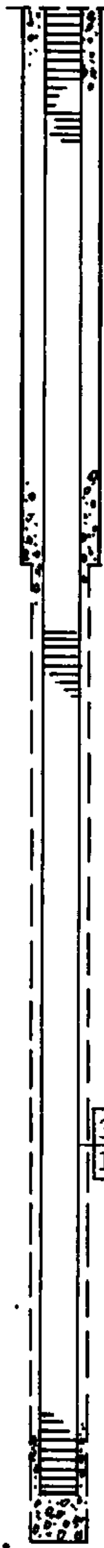
Project: Hat Creek Coal Development

Type of Drilling: Rotary
Rig: Bucyrus Erie
Drilling Fluid: Air

Coordinates E 19959
N 76477
Angle from Horizontal 90°
Bearing - ° Azimuth

Reference Elevation 3175
Type No.(9) 3
Purpose of Hole Geotechnical Study

* (1) Lithology	(2) Depth	Completed (2)(3) Construction	During Drilling: Depth (2)	During Drilling: W.L. (2)(4)	During Drilling: W.C. (5)	During Drilling: Other (6)	After Drilling: S.W.L. (2)(7)	After Drilling: Permeability D (2)(8)	After Drilling: Permeability K (8)	After Drilling: Permeability M (8)	Comments
	0										Lithology interpreted from RH 76-16A
Sand, Gravel, Till		12" I.D.									
	115										
	145										
		12"						145 400	10^{-8}	W	8" diameter slotted steel casing. Four slots 6" long, cut at 90° angles on circumference, and at 5 ft. vertical intervals.
Clayey Slst.											
		3,st 125									Pea size gravel pack placed in annular space outside well screen and steel casing, up to ground surface.
	388										
	400	T.D.									



Contractor: Tonto
Date started: 25/8/76
Date completed: 1/9/76

Logged by: DFF
Checked by: DFW
Date: 14/2/77

* NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 50 ft.

SUMMARY HYDROLOGIC LOG

DRILLHOLE No. RH-76-20
Sheet 1 of 1

Project: Hat Creek Coal Development
Type of Drilling: Rotary
Rig: Bucyrus Erie
Drilling Fluid: Air
Coordinates: E 23211, N 75277
Angle from Horizontal: 90°
Bearing: - ° Azimuth
Reference Elevation: 2953
Type No.(9): 3
Purpose of Hole: Geotechnical Study

Job No. V-76348 B

* (1) Lithology	(2) Depth m.	Completed Construction (2)(3)	During Drilling: Depth (2)	W.L. (2)(4)	W.C. (5)	Other (6)	After Drilling: S.W.L. (2)(7)	Permeability: D (2)(8)	K (8)	M (8)	Comments
	0										Lithology interpreted from DDH 76-821 (RH 76-21)
		6" I.D.									
Sand, Gravel, Till											
	55										
		1 60					-25				
	65										
	70										
		6½"									
Brecciated Slst.	85										
		6"									
	105	T.D.									

Contractor: Tonto
Date started: 10/9/76
Date completed: 12/9/76
Logged by: DFF
Checked by: DFW
Date: 14/2/77

*NOTE: Bracketed numbers refer to notes on pages A5-2 of this report.

Golder Associates

Vertical scale: 1 in. to 20 ft.

II) In Situ Permeability Testing

11) IN SITU PERMEABILITY TESTING

Falling head permeability tests were performed through the standpipe piezometers installed in six of the air-flush drill holes, (RH 76 Nos. 10-15) and in three diamond drill holes located in the proposed ash dump area (76-822, 76-823 and 76-824).

1. The water in each standpipe was allowed to stabilize to a static level.
2. Water was then poured into the standpipe to impose an excess pressure head of about 30 ft. of water at the test section.
3. The water level in the tube was then monitored until it approached the original elevation.
4. From a plot of pressure head vs. time (or depth below a fixed datum vs. time) the permeability constant was calculated by means of the following equation:

$$k = \frac{r^2 \ln (L/R)}{2L\ (t_2 - t_1)} \ln (H_1/H_2)$$

where k = permeability constant

r = radius of standpipe

L = length of isolated borehole section

R = radius of borehole

H_1 = pressure head of water in standpipe above static level at some point during the test

H_2 = pressure head at some later time

$t_2 - t_1$ = time interval between H_2 and H_1 measurement.

The results of these tests are summarized in Table A5-1.

TABLE A5-1 SUMMARY OF ALL PIEZOMETERS INSTALLED DURING 1976

		Piezometer No. 1 (4)					Piezometer No. 2					Piezometer No. 3				
Hole No.	Datum Elevation	Installation Depth (1)	Rock/Soil Type (5)	Piezometer Type	Piezometric Elevation (3)	Tested Permeability (2) (cm/sec)	Installation Depth (1)	Rock/Soil Type (5)	Piezometer Type	Piezometric Elevation (3)	Tested Permeability (2) (cm/sec)	Installation Depth (1)	Rock/Soil Type (5)	Piezometer Type	Piezometric Elevation (3)	Tested Permeability (2) (cm/sec)
DDH 76-801	3228	380 - 404	Clst., Slst.	Standpipe	3130											
DDH 76-802	3490	570 - 590	Sst.	Pneumatic	3499		39 - 50	Clay, Congl.	Standpipe	non-operational						
DDH 76-803	3170	550 - 596	Slst.	Standpipe	3149		58 - 68	Sand	Standpipe	3109		Annulus	-	Standpipe		
DDH 76-804	3531	361 - 382	Congl., Sst.	Pneumatic	non-operational		35 - 45	-	Standpipe	3503						
DDH 76-805	3362	287 - 295	Slst.	Pneumatic	3344		98	Sst.	Pneumatic	3356						
DDH 76-806	3376	455 - 469	Slst.	Standpipe	3342		60	Sst.	Pneumatic	3373						
DDH 76-807	3558	195 - 209	Sst.	Pneumatic	3514											
DDH 76-808	3086	561 - 574	Slst.	Standpipe	2904											
DDH 76-809	3081	459 - 474	Sst.	Standpipe	3018		Annulus	-	Standpipe	3058						
DDH 76-810	3023	292 - 300	-	Pneumatic	non-operational											
DDH 76-811	2951	381 - 398	Slst.	Standpipe	2914											
DDH 76-812	2825	317 - 338	Congl., Sst.	Standpipe	2810											
DDH 76-813	2881	373 - 387	Sand, Gravel	Standpipe	2754											
DDH 76-814	2971	679 - 700	Sst., Slst.	Standpipe	2924		328-336	Sand	Standpipe	2794						
DDH 76-815	3150	609 - 624	Slst.	Standpipe	2844											
DDH 76-816	3250	867 - 884	Basalt	Standpipe	3035		326-338	Slst., Sst.	Standpipe	3097						
DDH 76-817	2836	545 - 560	Slst.	Standpipe	2806											
DDH 76-818	3183	229 - 247	Slst., Sst.	Standpipe	3030											
DDH 76-819	2930	214 - 224	Sand, Gravel	Pneumatic	2819											
DDH 76-820	3084	195 - 207	Slst.	Standpipe	3078		51 - 58	Slst.	Standpipe	3076						
DDH 76-821	2963	227 - 240	Slst.	Standpipe	2952											
DDH 76-822	3943	123 - 149	Greenstone	Standpipe	dry	2.4×10^{-7}										
DDH 76-823	3947	68 - 82	Greenstone	Standpipe	3907	1.8×10^{-5}										
DDH 76-824	3855	152 - 174	Greenstone	Standpipe	3700	3.6×10^{-8}										
DDH 76-825	4600	35 - 50	Phyllite	Standpipe	4588											
DDH 76-826	4619	36 - 52	Phyllite	Standpipe	4606											
DDH 76-827	4603	43 - 58	Phyllite	Standpipe	4591											
DDH 76-828	4613	54 - 68	Phyllite	Standpipe	4601											
DDH 76-134	3335	540	Clst.	Standpipe	3297		66 - 72	Gravel	Standpipe	3292						
DDH 76-137	3397	238 - 259	Slst., Sst.	Standpipe	3395		Annulus									
DDH 76-138	3000	820 - 827	Sst. (basal)	Standpipe	2627		194-202	Coal	Standpipe	2842						
DDH 76-141	3342	1244-1257	Slst., Sst. (basal)	Standpipe	3279											
DDH 76-143	2897	338 - 352	Slst., Sst.	Standpipe	2824											
DDH 76-144	3136	1074-1084	Coal	Standpipe	3074											
DDH 76-146	2856	140	Sst.	Pneumatic	non-operational											
DDH 76-148	2969	284 - 295	Sst., Congl.	Standpipe	2820											
DDH 76-149	3268	1488-1508	Slst. (basal)	Standpipe	3182		118	Clay	Pneumatic	3217						
DDH 76-150	2891	220 - 414	Sst., Slst., Clst.	Standpipe	2638											
DDH 76-151	3019	1031-1038	Clst.	Standpipe	2867											
DDH 76-152	2823	383 - 400	Slst., Sst.	Standpipe	2812											
DDH 76-155	3169	779 - 793	Coal, Clst.	Standpipe	3109		84 - 92	Sand, Gravel	Standpipe	3119						
DDH 76-156	3035	560 - 575	Slst., Sst. (basal)	Standpipe	2870		190-204	Sand, Clay	Standpipe	dry						
DDH 76-158	3218	752 - 773	Slst., Sst. (basal)	Standpipe	3032											
DDH 76-160	3037	521 - 538	Slst., Sst. (basal)	Standpipe	2845		197-207	Sand, Gravel	Standpipe	2851						
DDH 76-161	3133	817 - 853	Slst. (basal)	Standpipe	2932		129-176	Clst.	Standpipe	3004						
DDH 76-163	3038	497 - 516	Slst. (basal)	Standpipe	non-operational		263-276	Sand, Coal	Standpipe	non-operational						
DDH 76-168	2943	130 - 142	Coal	Standpipe	283											
RH 76-10	3335	174 - 184	Sst.	Standpipe	3309	6.0×10^{-9}	143-158	Slst., Sst.	Standpipe	3264	5.3×10^{-9}	121-132	Clst.	Standpipe	3253	3.2×10^{-9}
RH 76-11	3397	136 - 150	Slst., Sst.	Standpipe	3342	5.7×10^{-9}	115-127	Sst.	Standpipe	3336	4.1×10^{-9}	83 - 95	Basalt	Standpipe	3332	1.8×10^{-4}
RH 76-12	3341	159 - 176	Slst.	Standpipe	3202	1.2×10^{-8}	133-149	Sst.	Standpipe	3286		108-120	Sst.	Standpipe	3296	
RH 76-13	3427	112 - 122	Slst., Congl.	Standpipe	3353	2.1×10^{-8}	86-101	Slst., Congl.	Standpipe	3349	9.5×10^{-9}	63 - 85	Slst., Clay	Standpipe	3355	1.4×10^{-8}
RH 76-14	3083	122 - 121	Slst.	Standpipe	2963	3.0×10^{-9}	94 - 110	Slst.	Standpipe	2991	1.9×10^{-9}	73 - 86	Slst.	Standpipe	3022	1.8×10^{-9}
RH 76-15	2823	197 - 208	Coal	Standpipe	2802	5.0×10^{-5}	170-181	Coal	Standpipe	2802	1.4×10^{-4}	142-155	Coal	Standpipe	2802	1.0×10^{-4}
RH 76-16	3182	149 - 159	Slst.	Pneumatic	3127											
RH 76-16A	3182	384 - 388	Slst.	Pneumatic	3142		226-246	Slst.	Pneumatic	3164						
RH 76-17	3172	390 - 403	Slst.	Pneumatic	3116		269-280	Slst.	Pneumatic	3130		156-165	Slst.	Pneumatic	3126	
RH 76-18	3194	387 - 400	Slst.	Pneumatic	3159		281-294	Slst.	Pneumatic	3167		182-192	Slst.	Pneumatic	3178	
RH 76-20	2953	55 - 65	Till	Standpipe	2927											

NOTES:
1) All depths are given in feet with respect to datum elevations (top of tube for stand pipes and ground level for pneumatic piez.).
2) Permeability tests were carried in situ using the falling head method.
3) Piezometric elevation as of November 1, 1976 except for RH 76-16, 16A, 17 and 18 which are readings taken prior to pumping test.
4) Piezometers are numbered from the deepest upwards.
5) See index to abbreviations in preamble to Appendix I, Volume 2.

III) Installation and Monitoring of Piezometers

III) INSTALLATION AND MONITORING OF PIEZOMETERS

Two types of piezometers were used, and were set in either cored mud-flush diamond-drill holes (3 to 4-inch diameter), or in air-flush rotary holes (6-inch diameter). A total of 74 standpipe piezometers and 19 pneumatic piezometers were installed. Details of the installations including typical designs are included in the last section and are summarized in Table A5-1.

All piezometer installations were designed as permanent installations to provide long-term monitoring of piezometric heads resulting from seasonal changes and pit excavation.

The piezometers were installed preferably in air-flush rotary holes, so that problems arising from the mudded walls of the holes were obviated. However advantage was also taken of the large number of mud-flush holes being drilled to install instruments wherever practicable. In the deeper holes, where the hole walls were difficult to stabilize, piezometer installations had to be completed through the drill rods after geophysical logging had been carried out. Piezometers were set in nests of one, two and occasionally three per hole, and only one hole had four piezometers (RH 76-15). The upper piezometers were usually set quite easily in the open hole after removal of the drill rods and before collapse of the hole.

The piezometers installed during the 1976 drilling program have been useful in providing initial piezometric head values. Many of the piezometers installed during July and August are still dropping slightly, and appear to be slowly stabilizing. The slow response in some of the standpipe piezometers is not surprising considering the low permeability of the siltstone and claystone (approx. 10^{-8} cm/sec.). Figure A5-1 shows hydrographs of piezometers in two holes, (DDH 76-801 and 76-805), which illustrate the response curves experienced in different areas with different piezometer types. The standpipe piezometer in

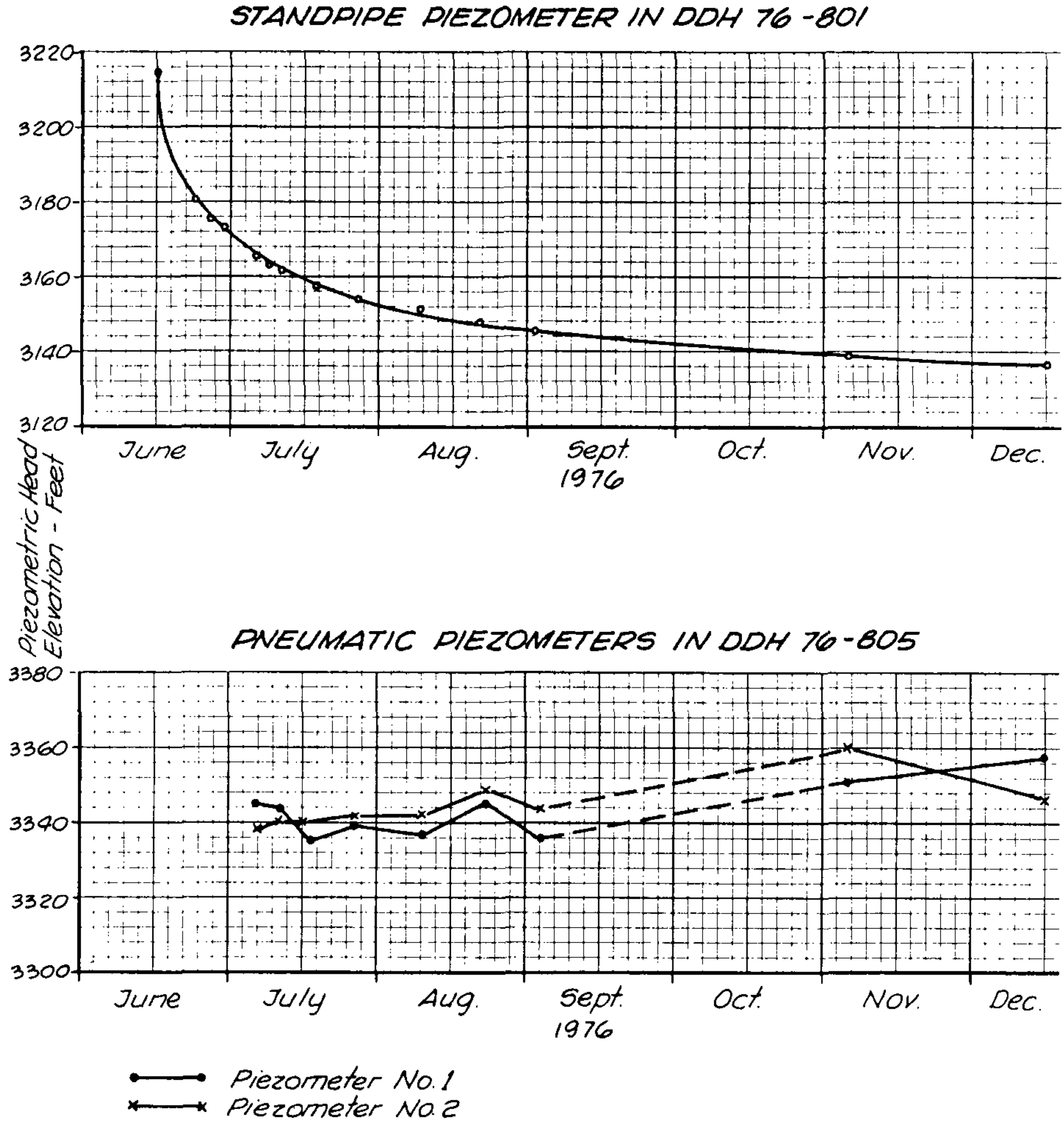
DDH 76-801 is located in siltstone on the southeastern pit perimeter, and the hydrograph shows a gradual decline of the water level in the standpipe. The two pneumatic piezometers in DDH 76-805 showed significant changes during the same period, thus demonstrating the sensitivity of these piezometers in low permeability sediments.

A regular monthly monitoring program for all piezometers has been recommended by GA, and it is being carried out by DCA for BCH. This program should be continued.

Project No. V-76348B

HYDROGRAPHS OF PIEZOMETERS 76-801-1, 76-805-1 AND 76-805-2

Figure A5-1



Golder Associates

Drawn ____
Reviewed ____
Date Mar. '77

IV) Report on Chemical Analysis of Water Samples

IV) CANTEST LIMITED REPORT ON THE INORGANIC CHEMICAL ANALYSIS OF WATER SAMPLES

Five water samples were collected from creeks, springs and the pump test well and were submitted to Cantest Limited for inorganic chemical analyses. Their report is attached, and the following sampling sites correspond with the sampling numbers given:

GA Sample No.	Sample Site
76-1	Aleece Creek: 2,000 ft. from lake outlet
76-2	Spring: on south shore of Aleece Lake
76-3	Aleece Lake: at 2 ft. depth near outlet
76-4	Well RH 76-19: during development
76-5	Hat Creek: near borehole RH 76-20
76-6	Well RH 76-19: at end of pump test

These data are summarized along with isotope data in Table 3 in the Main Report.

can test ltd.

1650 PANDORA STREET, VANCOUVER, B.C. V5L 1L6 • TELEPHONE 254-7278 • TELEX 04-54210

Report On Water Samples for Chemical Analysis

File No. 4780 B

Report No.

Reported to Golder Associates,

Consulting Geotechnical Engineers,

224 W. 8th Avenue,

Vancouver, B.C.

Date Nov. 9, 1976

Atten: R. Allan Dakin

Re: Hat Creek Project

We have tested the samples of water submitted by you on October 22, 1976 and report as follows:

SAMPLE IDENTIFICATION:

The samples were submitted in plastic bottles labelled -

- Aleece Creek - 76 - 1
  76 - 3
  76 - 4
  76 - 5
  76 - 6

METHOD OF TESTING:

The samples were tested in accordance with the procedures set down in "Standard Methods for the Examination of Water and Wastewater" - 13th Edition, published by the American Public Health Association, 1975. Some of the samples were small, and for this reason Calcium, Magnesium, and Sodium were analysed by Plasma Spectroscopy rather than traditional methods.

RESULTS OF TESTING:

(on following page)

RESULTS OF TESTING:

Test Parameter		76 - 1	76 - 3	76 - 4	76 - 5	
pH		7.85	7.60	7.60	8.0	
Conductivity		508.	508.	677.	462	micromhos cm
Dissolved Cations						
Calcium	Ca^{++}	44.8	33.9	19.0	58.0	ppm
Magnesium	Mg	21.7	25.2	9.4	17.1	ppm
Sodium	Na	33.0	38.0	110.	21.3	ppm
Potassium	K	9.0	11.5	18.0	4.0	ppm
Iron	Fe	-	L 0.05	-	-	ppm
Dissolved Anions						
Bicarbonates	HCO	-	265.	260.	-	ppm
Sulfate	SO_4	-	52.2	47.7	-	ppm
Chloride	Cl	-	L 0.5	L 0.5	-	ppm
Total Hardness	$CaCO_3$	201.	188.	86.0	214.	ppm

(con't on following page)

RESULTS OF TESTING:

		# 76 - 6	
pH		7.60	
Conductivity		1834.	micromhos/cm
Total Hardness	$CaCO_3$	208.	ppm
Dissolved Anions			
Alkalinity			
Bicarbonates	HCO_3	1150.	ppm
Carbonates	CO_3	NIL	ppm
Hydroxyl Ion	OH	NIL	ppm
Chlorides	Cl	L 0.5	ppm
Sulfates	SO_4	17.3	ppm
Nitrates	N	L 0.10	ppm
Nitrites	N	L 0.001	ppm
Phosphates	PO_4	L 0.01	ppm
Fluoride	F	0.067	ppm
Dissolved Cations			
Calcium	Ca	47.7	ppm
Magnesium	Mg	21.6	ppm
Potassium	K	34.0	ppm
Sodium	Na	330.	ppm
Iron	Fe	L 0.05	ppm
Aluminum	Al	0.004	ppm
Arsenic	As	L 0.005	ppm
Cadmium	Cd	L 0.001	ppm
Chromium	Cr	L 0.001	ppm
Copper	Cu	0.007	ppm
Mercury	Hg	L 0.0002	ppm
Lead	Pb	0.020	ppm
Zinc	Zn	1.97	ppm
Boron	B	L 0.1	ppm
Selenium	Se	L 0.004	ppm
Strontium	Sr	0.06	ppm
Lithium	L	L 0.05	ppm
Vanadium	V	L 0.10	ppm
Total Kjeldahl Nitrogen		22.2	ppm
Total Dissolved Solids		1600.	
Fixed		1400.	
Volatile		200.	

L - less than

CAN TEST LTD.,

A. W. Maynard,MSc
Chemist.

/dn

APPENDIX 6

PUMP TEST REPORT
FOR BOREHOLE RH 76-19

APPENDIX 6

PUMP TEST REPORT FOR BOREHOLE RH 76-19

LOCATION AND CONSTRUCTION OF TEST WELL AND OBSERVATION PIEZOMETERS

A 23-day pumping test was carried out on borehole RH 76-19 which is located slightly south of the middle of the proposed pit, see Drawing 6 (main text). The hole was constructed by first drilling and casing a 12-inch diameter hole to a depth of 145 ft. and then drilling an open hole to 400 ft. depth. The hole was drilled using a rotary drilling rig with an air-flush system. An 8-inch steel casing, which had perforations cut into the lower 255 ft., was then set into the hole and the annular space was backfilled with pea-gravel (see details in the Hydrologic Log for borehole RH 76-19 in Appendix 5). The completed hole was surged with air for about 3 days until the formation material had stabilized. Four observation holes were drilled within a radius of 360 ft. of this pump well, were completed at depths of about 400 ft. using biodegradable mud, and up to three piezometers were installed in each hole (see construction details, Appendix 5).

GEOLOGY AND HYDROLOGY OF TEST SITE

The pumped well (RH 76-19) was drilled into the upper claystone-siltstone member of the Coldwater Formation (see Drawing A6-1). The surficial deposits at the site were about 100 ft. thick and were comprised of till with minor inter-beds of sand and gravel. These surficial deposits were cased off to prevent vertical seepage into the well. The well screen (i.e. slotted portion of 8-inch casing) penetrated about half of the siltstone-claystone aquifer unit (see Section B-B, Drawing A6-1). This aquifer is not areally extensive as it is shaped like a narrow trough approximately 1,000 ft. wide and running parallel to the axis of Hat Creek. This trough rests on top of a folded 700 ft. thick layer of coal (see Sections A-A and B-B, Drawing A6-1).

An examination of the piezometric heads in the aquifer prior to the start of the pump test show the following:

a) the piezometric heads are generally about 50-90 ft. below ground level (i.e. in the till above the Coldwater Formation) and hence the till could be acting as a confining layer for ground water in the Coldwater Formation.

b) the sand and gravel layer around RH 76-18 is a source of local recharge to the Coldwater Formation. This is not surprising as flows of about 60 gpm were encountered while drilling this borehole.

c) the ground water generally flows downwards and follows the general slope of the topography, except in the area of RH 76-18 where local recharge disturbs this pattern.

PUMP TEST PROCEDURE

A small (1 h.p.) submersible pump was set in the 8-inch well to a depth of 380 ft. below ground. In order to reduce the water flows and line pressures at the ground surface, a small pipe-tee with an orifice plate was installed in the drop pipe just above the submersible pump. This allowed some water to escape back into the well, and hence reduced the line pressures. The water discharge from the well was controlled by means of a small needle valve.

In order to ensure that no water could seep back into the ground the pumped water was directed into a large mud pit. The pump test was started on

September 22, 1976 and the initial pumping rate was 1 gpm for the first three hours. The test had to be suspended for 19 hours while a malfunctioning generator was repaired and then the 1 gpm pumping rate was resumed. As very little recovery had been recorded in either the well or the observation piezometers, the effects of the suspension in pumping was small in relation to the length of the test that was carried out. After two days the pumping rate was reduced to 0.5 gpm, on the 3rd day the rate was reduced again to 0.1 gpm and this pumping rate was maintained for the remainder of the 23-day test. While the pump test was running, water levels and pneumatic pressures were read in the pumped well and in the piezometers around the well (see list of all measurements in pump test data summary in this appendix). In addition samples of the water pumped from the well were collected at the start and at the end of the pump test. These samples were sent for chemical and isotope analyses (see summary of results in Table 3 of the main report). Water temperatures and the electrical conductivity of the pumped water were measured at intermittent intervals during the pumping test (see data given in remarks column of pump test data summary in this appendix).

At the end of the test the pump was turned off and the response in the piezometers were monitored. An automatic water level recorder was installed in standpipe piezometer DDH 76-149-1.

ANALYSIS OF PUMP TEST DATA

The water level and pneumatic pressure readings were converted to piezometric elevations and drawdown, and are shown plotted in Figures A6-1 and A6-2. These figures show that the piezometric levels in the pumped well and the piezometers responded very rapidly at the start of the test, but after about 6 days of pumping most piezometers had stabilized and remained relatively stable for the remainder of the test.

Log-log graphs of drawdown versus time since pumping started were plotted for all piezometers and type curves were constructed so that hydrogeologic parameters, transmissivity and storage coefficients could be calculated. The type curves were constructed by modifying the standard Theis curve to account for the following:

1) partial penetration of the aquifer (Walton, 1972 p. 215);*
2) aquifer anisotropy: vertical permeability (k_v) to horizontal permeability k_h ratio is assumed to be 1:10 (Boulton and Streltsova, 1976);
3) large diameter of well relative to pumping rate (Boulton and Streltsova, 1976);
4) leakage of water from more permeable sand and gravel zones in the surficial till unit above the aquifer (Walton, 1972, p. 217).

Examples of plotted data and calculations using the modified type curve are given in pump test data summary sheets for piezometers RH 76-17-1, RH 76-18-2, DDH 76-149-1 and DDH 76-149-2. A summary of the results of calculations for all piezometers are given in Table A6-1. Similar type curves were used to calculate parameters from log-log distance-drawdown plots. These type curves incorporated the modifications previously described. The results of these calculations are shown in Table A6-2 for the periods 12 days and 23 days after the test started.

Because of the large diameter of the pumped well relative to the aquifer permeability, the recovery method of aquifer analysis (Walton, 1972) would not be easy to analyze and hence was not used.

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*See List of References and Glossary in Section 9. of the main text.

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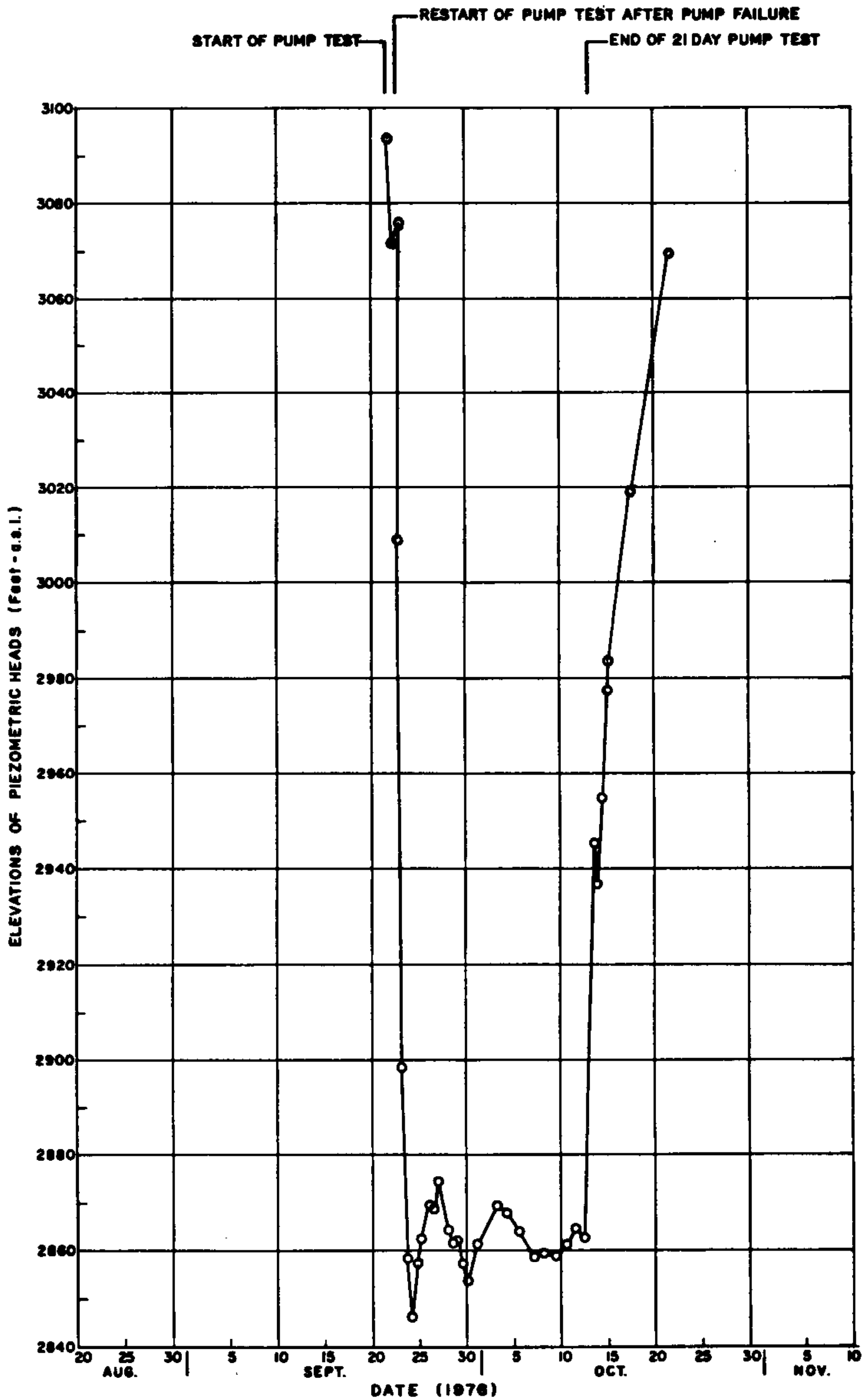
ELEVATIONS OF WATER LEVELS IN PUMPED WELL RH76-19 DURING PUMP TEST.

FIGURE A6-1



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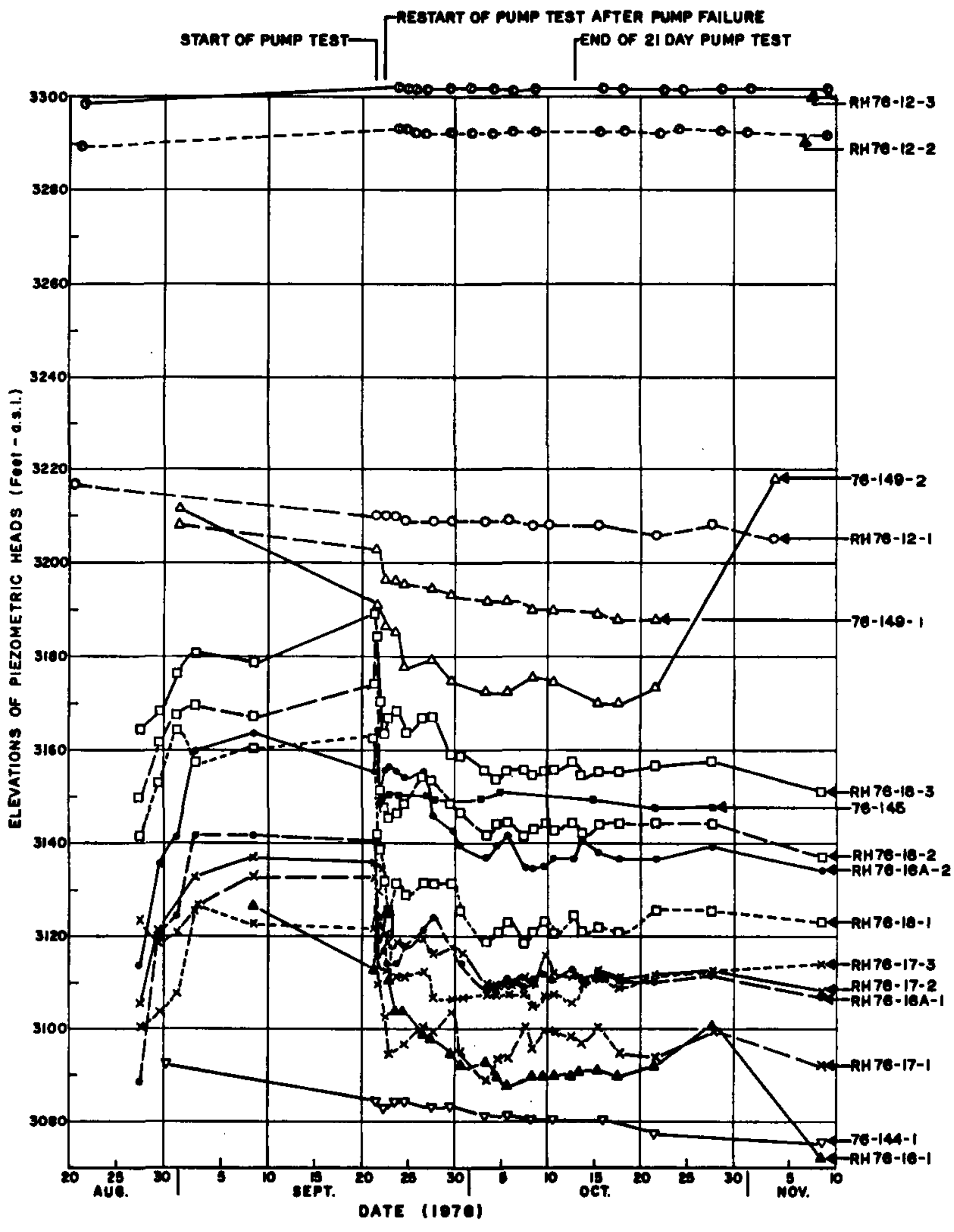
G.B. 105

Project No. V7623488

ELEVATIONS OF PIEZOMETRIC HEADS IN OBSERVATION HOLES: BEFORE, DURING AND SUBSEQUENT TO PUMPING TEST OF RH76-19.

FIGURE A6-2



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DISCUSSION OF RESULTS

1) The calculated aquifer transmissivity ("T") of the siltstone-claystone aquifer ranges between 0.20-1.15 gpd/ft. and averages 0.7 gpd/ft. for the piezometers around the well (Table A6-1). If we assume that the average aquifer thickness is about 600 ft., then the calculated horizontal permeability of the aquifer would be 5.3×10^{-8} cm/sec. This figure is in reasonable agreement with the permeability figures determined using the falling head method in standpipe piezometers, see Table A5-1. For example in piezometer RH 76-12-1 which is located 1,400 ft. from the pumped well the calculated permeability is $k = 1.2 \times 10^{-8}$ cm/sec.

2) The calculated storage coefficients (S) ranged from 0.21×10^{-7} to 9×10^{-7} and averaged 4×10^{-7} for the piezometers around the well (Table A6-1). Assuming a 600 ft. aquifer thickness the average specific storage (see Glossary) would be $4 \times 10^{-7}/600 = 6.7 \times 10^{-10}$ $ft^{-1} = 2.2 \times 10^{-11}$ cm^{-1}.

3) The pump test showed that ground water in the sands and gravels in the till above the aquifer was recharging water to the siltstone-claystone aquifer. Evidence for this was observed in both the piezometric head pattern near the well (see Section A-A, Drawing A6-1) and in the response shown in piezometer DDH 76-149-2. This latter piezometer is located in the till and showed a 25-ft. decline in piezometric head during the pump test.

4) The pump test showed that there is a hydraulic connection between the A-zone coal, B-zone coal and sandstone-siltstone unit below. This statement is based on observations in piezometers DDH 76-149-1 and DDH 76-144-1 which both show a response as a result of pumping well RH 76-19.

5) The more permeable coal ($k = 10^{-4}$ cm/sec.) zones are sufficiently far from the well to have no influence on the calculations for transmissivity.

CONCLUSIONS

1) The pump test has shown that some depressurization had taken place in the sediments around the pump test site.

2) The siltstone-claystone (Coldwater Formation) sediments have a permeability of about 10^{-8} cm/sec. and specific storage of about 2×10^{-11} cm^{-1}.

3) The test demonstrated that the surficial deposits are recharging the Coldwater Formation and that it will be essential to dewater these surficial deposits before the siltstone can be effectively depressurized.

TABLE A6-1

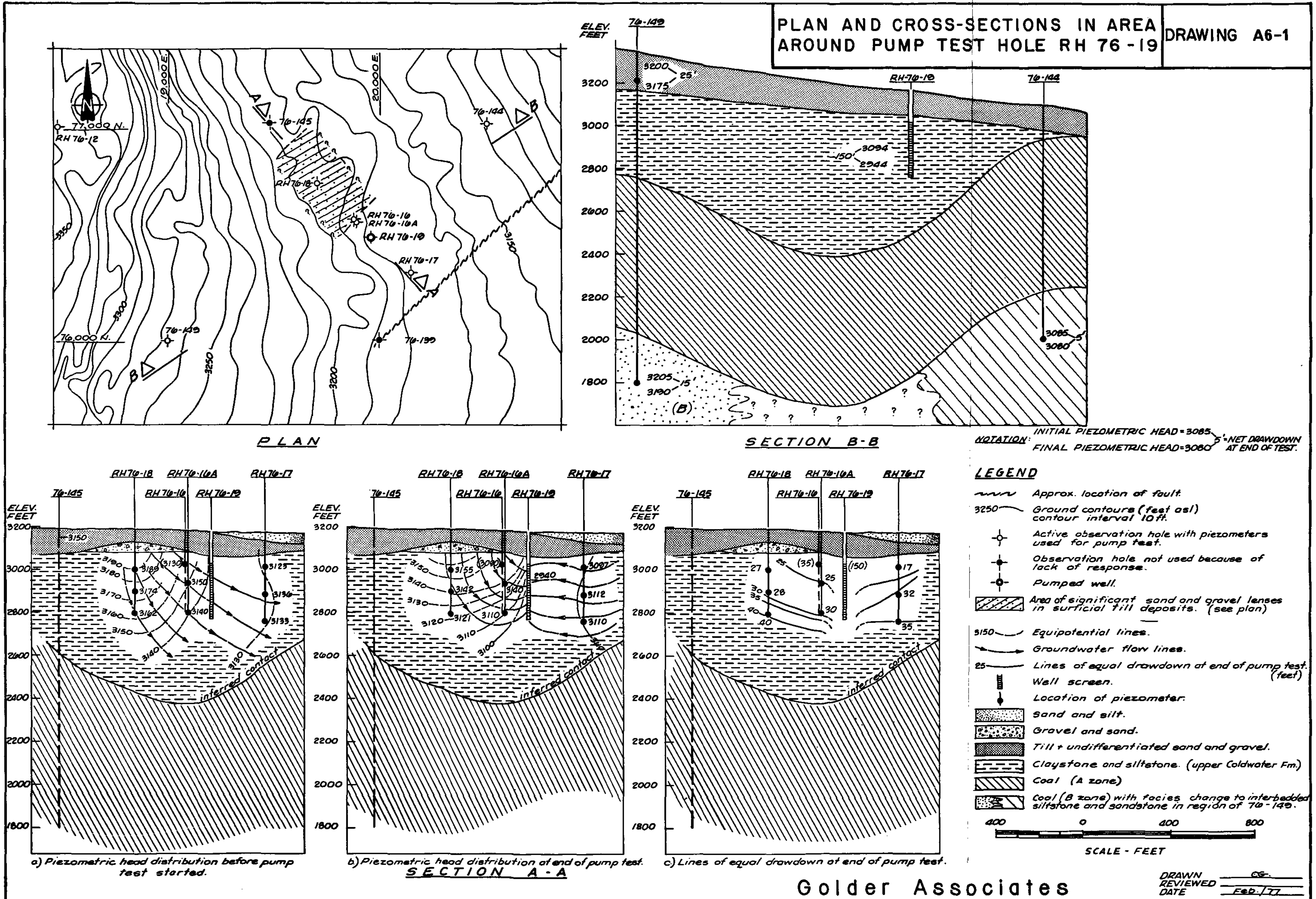
HYDROGEOLOGIC PARAMETERS CALCULATED FROM TIME-DRAWDOWN CURVES

Observation Point	Distance From Pumped Well (ft)	Aquifer Parameter Transmissivity T (gpd/ft)	Storage Coefficient S x 10^{-7}
RH 16A-1	105	0.21	5.3
RH 16A-2	105	0.20	6
RH 16-1	115	0.7	2
RH 17-1	249	0.64	0.35
RH 17-2	249	1.04	1.13
RH 17-3	249	0.76	9
RH 18-1	357	0.76	0.21
RH 18-2	357	0.96	0.28
RH 18-3	357	1.15	0.67
Average		0.71	4.1
DDH 144-1	760	1.15	0.66
DDH 149-1	1080	0.5	0.52
DDH 149-1	1080	0.5	0.52
DDH 149-2	1080	0.29	0.91

TABLE A6-2

HYDROGEOLOGIC PARAMETERS CALCULATED FROM DISTANCE-DRAWDOWN CURVES

Time Since Pumping Started (days)	Aquifer Parameter Transmissivity T gpd/ft.	Storage Coefficient S
12	0.2	$2x10^{-5}$
23	0.13	$7.8x10^{-6}$



PLAN AND CROSS-SECTIONS IN AREA AROUND PUMP TEST HOLE RH 76-19
DRAWING A6-1
PLAN
SECTION B-B
SECTION A-A
a) Piezometric head distribution before pump test started.
b) Piezometric head distribution at end of pump test.
c) Lines of equal drawdown at end of pump test.
NOTATION: INITIAL PIEZOMETRIC HEAD=3085 5'=NET DRAWDOWN AT END OF TEST. FINAL PIEZOMETRIC HEAD=3080
LEGEND
Approx. location of fault.
Ground contours (feet asl) contour interval 10 ft.
Active observation hole with piezometers used for pump test.
Observation hole not used because of lack of response.
Pumped well.
Area of significant sand and gravel lenses in surficial till deposits. (see plan)
Equipotential lines.
Groundwater flow lines.
Lines of equal drawdown at end of pump test. (feet)
Well screen.
Location of piezometer.
Sand and silt.
Gravel and sand.
Till + undifferentiated sand and gravel.
Claystone and siltstone. (upper Coldwater Fm)
Coal (A zone)
Coal (B zone) with facies change to interbedded siltstone and sandstone in region of 76-149.
SCALE - FEET
400 0 400 800
ELEV. FEET
76-149
76-144
76-145
76-199
RH 76-12
RH 76-16
RH 76-16A
RH 76-17
RH 76-18
RH 76-19
77,000 N.
76,000 N.
19,000 E.
20,000 E.
inferred contact
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DRAWN CG.
REVIEWED
DATE Feb./77

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PUMP TEST DATA SUMMARY

Observations in RH 76-12-1
Sheet 1 of 1

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [ ] Pneumatic piezo. [X] Standpipe piezo.

Datum point Top of tube
Depth to static water level 136 FT.
Screened/open hole interval ____ to ____

Datum elevation 3346 FT. a.s.l.
Elevation static water level 3210 FT. a.s.l.
Elevation of screened interval ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth 400 feet
Well diameter 8 inches
Pump type Electric Submersible
Final pumping rate 0.1 gpm

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description Coldwater Fm (Siltstone)
Aquifer thickness 800 feet
Depth to pump suction 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	15	00	0	136.1		3209.9	-		
	16	00	0	-		-	-		Pump started
23	11	30	1170	136.4		3209.6	7.4		
24	15	30	2850	136.4		3209.6	7.4		
25	14	00	4200	136.6		3209.4	7.6		
28	14	30	8550	136.7		3209.3	7.7		
30	14	00	11400	137		3209	8.0		
4	9	30	16890	137.2		3208.8	8.2		
6	17	00	20220	137.3		3208.7	8.3		
9	10	00	24120	138		3208	9.0		
11	15	00	27300	138		3208	9.0		
14	19	11	31871	-		-	-		Pump stopped
16	11	00		138.1		3207.9	9.1		
18	15	20		-		-	-		
22	15	30		141.9		3204.1	12.9		
28	15	30		138.2		3207.8	9.2		
10	15	30		139		3207.0	10.0		

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PUMP TEST DATA SUMMARY

Observations in RH 76-12-2
Sheet 1 of 1

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [ ] Pneumatic piezo. [X] Standpipe piezo.

Datum point Top of tube
Depth to static water level 55 FT.
Screened/open hole interval ____ to ____
Datum elevation 3346 FT. a.s.l.
Elevation static water level 3291 FT. a.s.l.
Elevation of screened interval ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth 400 feet
Well diameter 8 inches
Pump type Electric Submersible
Final pumping rate 0.1 gpm

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description Coldwater Fm (Siltstone)
Aquifer thickness 800 feet
Depth to pump suction 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	15	00	0	53.3		3292.7	-		
	16	00	0	-		-	-		Pump started
23	11	30	1170	52.0		3294	3.0		
24	15	30	2850	52.6		3293.4	2.4		
25	14	00	4200	52.5		3293.5	2.5		
28	14	30	8550	52.5		3293.5	2.5		
30	14	00	11400	52.5		3293.5	2.5		
4	9	30	16890	52.4		3293.6	2.6		
6	17	00	20220	52.6		3293.4	2.4		
9	10	00	24120	-		-	-		
11	15	00	27300	-		-	-		
14	19	11	31871	-		-	-		Pump stopped
16	11	00		52.5		3293.5	2.5		
18	15	20		-		-	-		
22	15	30		52.6		3293.4	2.4		
28	15	30		52.4		3293.6	2.6		
10	15	30		52.9		3293.1	2.1		

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PUMP TEST DATA SUMMARY

Observations in RH 76-12-3
Sheet 1 of 1

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

DATE: Start: Sept. 22, 1976
Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [ ] Pneumatic piezo. [X] Standpipe piezo.

Datum point: Top of tube
Depth to static water level: 46 FT.
Screened/open hole interval: ______ to ______
Datum elevation: 3346 FT. a.s.l.
Elevation static water level: 3300 FT. a.s.l.
Elevation of screened interval ______ to ______ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth: 400 feet
Well diameter: 8 inches
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description: Coldwater Fm (Siltstone)
Aquifer thickness: 800 feet
Depth to pump suction: 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	15	00	0	44.2		3301.8	-		
	16	00	0	-		-	-		Pump started
23	11	30	1170	43.5		3302.5	2.5		
24	15	30	2850	43.6		3302.4	2.4		
25	14	00	4200	43.5		3302.5	2.5		
28	14	30	8550	43.6		3302.4	2.4		
30	14	00	11400	43.6		3302.4	2.4		
4	9	30	16890	43.5		3302.5	2.5		
6	17	00	20220	43.8		3302.2	2.2		
9	10	00	24120	-		-	-		
11	15	00	27300	-		-	-		
14	19	11	31871	-		-	-		Pump stopped
16	11	00		43.8		3302.2	2.2		
18	15	20		-		-	-		
22	15	30		43.8		3302.2	2.2		
28	15	30		43.8		3302.2	2.2		
10	15	30		44.0		3302	2.0		

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PUMP TEST DATA SUMMARY

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

Observations in RH 76-16
Sheet 1 of 2

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [X] Pneumatic piezo. [ ] Standpipe piezo.

Datum point Top of tube
Depth to static water level –
Screened/open hole interval ____ to ____
Datum elevation 3182.1 FT. a.s.l.
Elevation static water level – a.s.l.
Elevation of screened interval ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth 400 feet
Well diameter 8 inches
Pump type Electric Submersible
Final pumping rate 0.1 gpm

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description Coldwater Fm (Siltstone)
Aquifer thickness 800 feet
Depth to pump suction 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	9	00			38		-		
	16	0	0		-	3126.1	-		Pumping started
	16	30	30	48.4	47	3133.7	-		
	19	00	180	60.0	42	3122.1	4.0		
23	11	30	1170	57.7	43	3124.4	1.7		
	19	30	1650	71.5	37	3110.6	15.5		
24	15	30	2850	78.5	34	3103.6	22.5		
25	13	30	4170	78.5	34	3103.6	22.5		
27	14	00	7080	83.1	32	3099.0	27.1		
28	14	30	8550	89.2	31.5	2097.9	28.2		
30	14	00	11400	87.7	30	3094.4	31.7		
1	15	45	12945	90.0	29	3092.1	34.0		
4	9	30	16890	90.0	29	3092.1	34.0		
5	13	00	18540	92.3	28	3089.8	36.3		
6	17	00	20220	94.6	27	3087.5	38.6		
8	11	00	22840	-	-	-	-		
9	9	00	24060	92.3	28	3089.8	36.3		
10	15	30	25890	92.3	28	3089.8	36.3		
11	15	00	27300	92.3	28	3089.8	36.3		
13	14	00	30120	92.3	28	3089.8	36.3		
14	17	30	31770	91.2	28.5	3090.9	35.2		Pumping stopped (19:11)
16	11	15		91.2	28.5	3090.9	35.2		
18	16	00		92.3	28	3089.8	36.3		
22	15	30		90.0	29	3092.1	34.0		
28	15	30		80.8	33	3101.3	24.8		

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PUMP TEST DATA SUMMARY

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

Observations in RH 76-16
Sheet 2 of 2

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
10	15	30		109.6	20.5	3024.1	53.6		

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Project No. V76348B

PUMP TEST DATA SUMMARY

Observations in RH 76-16A-1
Sheet 1 of 2

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

DATE: Start: Sept. 22, 1976 Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [X] Pneumatic piezo. [ ] Standpipe piezo.

Datum point: Top of tube
Depth to static water level: 40.6 FT.
Screened/open hole interval: ____ to ____
Datum elevation: 3182.1 FT. a.s.l.
Elevation static water level: 3141.5 a.s.l.
Elevation of screened interval: ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth: 400 feet
Well diameter: 8 inches
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description: Coldwater Fm (Siltstone)
Aquifer thickness: 800 feet
Depth to pump suction: 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	9	00	0	41.5	150	3140.6			
	16	00	0		-	-	-		Pumping started.
	16	30	30	40.3	150.5	3141.8	0		
	19	00	180	66.9	139	3115.2	26.3		
23	11	30	1180	64.6	140	3117.5	24.0		
	19	30	1650	68.1	138.5	3114.0	27.5		
24	15	30	2850	68.1	138.5	3114.0	27.5		
25	13	30	4170	64.6	140	3117.5	24.0		
27	14	00	7080	61.1	141.5	3121.0	20.5		
28	14	30	8550	58.8	142.5	3123.3	18.2		
30	14	00	11400	64.6	140	3117.5	24.0		
1	15	45	12945	68.1	138.5	3114.0	27.5		
4	9	30	16890	73.8	136	3108.3	33.2		
5	13	00	18540	73.8	136	3108.3	33.2		
6	7	00	20220	71.5	137	3110.6	30.9		
8	11	00	22740	73.8	136	3108.3	33.2		
9	9	00	24060	71.5	137	3110.6	30.9		
10	15	30	25890	70.4	137.5	3111.7	29.8		
11	15	00	27300	71.5	137	3110.6	30.9		
13	14	00	30120	69.2	138	3112.9	28.6		
14	17	30	31770	71.5	137	3110.6	30.9		Pump stopped (19:11)
16	11	15		70.4	137.5	3111.7	29.8		
18	16	00		71.5	137	3110.6	30.9		
22	15	30		71.5	137	3110.6	30.9		
28	15	30		70.4	137.5	3111.7	29.8		

Golder Associates

Logged by RAB

Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

Observations in RH 76-16A-1
Sheet 2 of 2

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
10	5	30		75	135.5	3107.1	34.4		

Golder Associates

Logged by RAG

Project No. V763488

PUMP TEST DATA SUMMARY

Observations in RH 76-16A-2
Sheet 1 of 2

PROJECT Hot Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [X] Pneumatic piezo. [ ] Standpipe piezo.

Datum point Top of tube
Depth to static water level 19.6 FT.
Screened/open hole interval ____ to ____
Datum elevation 3182.1 FT. a.s.l.
Elevation static water level 3163.5 FT. a.s.l.
Elevation of screened interval ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth 400 feet
Well diameter 8 inches
Pump type Electric Submersible
Final pumping rate 0.1 gpm

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description Coldwater Fm (Siltstone)
Aquifer thickness 800 feet
Depth to pump suction 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	9	00	0	26.9	94	3155.2			
	16	00	0	-	-	-	-		Pumping started
	16	30	30	17.6	98	3164.5	-		
	19	00	180	33.8	91	3148.3	15.2		
23	11	30	1170	26.9	94	3155.2	8.3		
	19	30	1650	25.7	94.5	3156.4	7.1		
24	15	30	2850	26.9	94	3155.2	8.3		
25	13	30	4170	28.0	93.5	3154.1	9.4		
27	14	00	7080	26.9	94	3155.2	8.3		
28	14	30	8550	36.1	90	3146.0	17.5		
30	14	00	11400	39.6	88.5	3142.5	21.0		
1	15	45	12945	43.0	87	3139.1	24.4		
4	9	30	16890	45.3	86	3136.8	26.7		
5	13	00	18540	43.0	87	3139.1	24.4		
6	17	00	20220	40.7	88	3141.4	22.1		
8	11	00	22740	47.6	85	3134.5	29.0		
9	9	00	24060	47.6	85	3134.5	29.0		
10	15	30	25890	47.6	85	3134.5	29.0		
11	15	00	27300	45.3	86	3136.8	26.7		
13	14	00	30120	45.3	86	3136.8	26.7		
14	17	30	31770	41.9	87.5	3140.2	23.3		Pumping stopped (19:11)
16	11	15		44.2	86.5	3137.9	25.6		
18	16	00		45.3	86	3136.8	26.7		
22	15	30		45.3	86	3136.8	26.7		
28	15	30		43.0	87	3139.1	24.4		

Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

Observations in RH 76-16A-2
Sheet 2 of 2

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
10	15	30		47.6	85	3134.5	29.0		

Golder Associates

Logged by RAB

Project No. V7634888

PUMP TEST DATA SUMMARY

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

Observations in: RH 17-1
Sheet 1 of 8

DATE: Start: Sept. 22, 1976
Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [X] Pneumatic piezo. [ ] Standpipe piezo.

Datum point: Top of tube
Datum elevation: 3179 FT. a.s.l.
Depth to static water level: 46.5 FT.
Elevation static water level: 3132.5 FT. a.s.l.
Screened/open hole interval ____ to ____
Elevation of screened interval ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description: Coldwater Fm (Siltstone)
Well depth: 400 feet
Aquifer thickness: 800 feet
Well diameter: 8 inches
Depth to pump suction: 370 feet
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	9	00	0	46.3	154	3132.7			
	16	00	0		-		-		Pump started
	16	30	30	55.5	150	3123.5	0		
	19	00	180	69.4	144	3109.6	22.9		Pump stopped @ 150 mins.
23	11	30	1170	76.3	141	3102.7	29.8		
	19	30	1650	84.4	137.5	2094.6	37.9		Pump restarted @ 1290
24	15	30	2850	75.1	141.5	3103.9	28.6		
25	13	30	4170	82.1	138.5	3096.9	35.6		
27	14	00	7080	78.6	140	3100.4	32.1		
28	14	30	8550	79.8	139.5	3099.2	33.3		
30	14	00	11400	75.1	141.5	3103.9	28.6		
1	15	45	12945	84.4	137.5	3094.6	37.9		
4	9	30	16890	90.1	135	3088.9	43.6		
5	13	00	18540	85.5	137	3093.5	39.0		
6	17	00	20220	85.5	137	3093.5	39.0		
8	11	00	22740	78.6	140	3100.4	32.1		
9	9	00	24060	83.2	138	3095.8	36.7		
10	15	30	25890	79.8	139.5	3099.2	33.3		
11	15	00	27300	79.8	139.5	3099.2	33.3		
13	14	00	30120	80.9	139	3098.1	34.4		
14	17	30	31770	82.1	138.5	3096.9	35.6		Pump stopped (19:11)
16	11	15		88.6	140	3100.4	32.1		
18	16	00		84.4	137.5	3094.6	37.9		
22	15	30		85.5	137	3093.5	39.0		
28	15	30		79.8	139.5	3099.2	33.3		

Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

Observations in: RH 17-1
Sheet 2 of 3

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

Time			Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
Dy.	Hr.	Min.							
10	15	30		86.7	136.5	3092.5	40.2		

Golder Associates

Logged by: RAQ

Project No. V7634AB

PUMP TEST DATA SUMMARY

Observations in	RH76-17-1
Sheet 3 of 3	

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

DATE: Start: Sept. 22, 1976 Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [X] Pneumatic piezo. [ ] Standpipe piezo.

Datum point: Top of tube
Depth to static water level: 46 ft.
Screened/open hole interval: 391 to 404

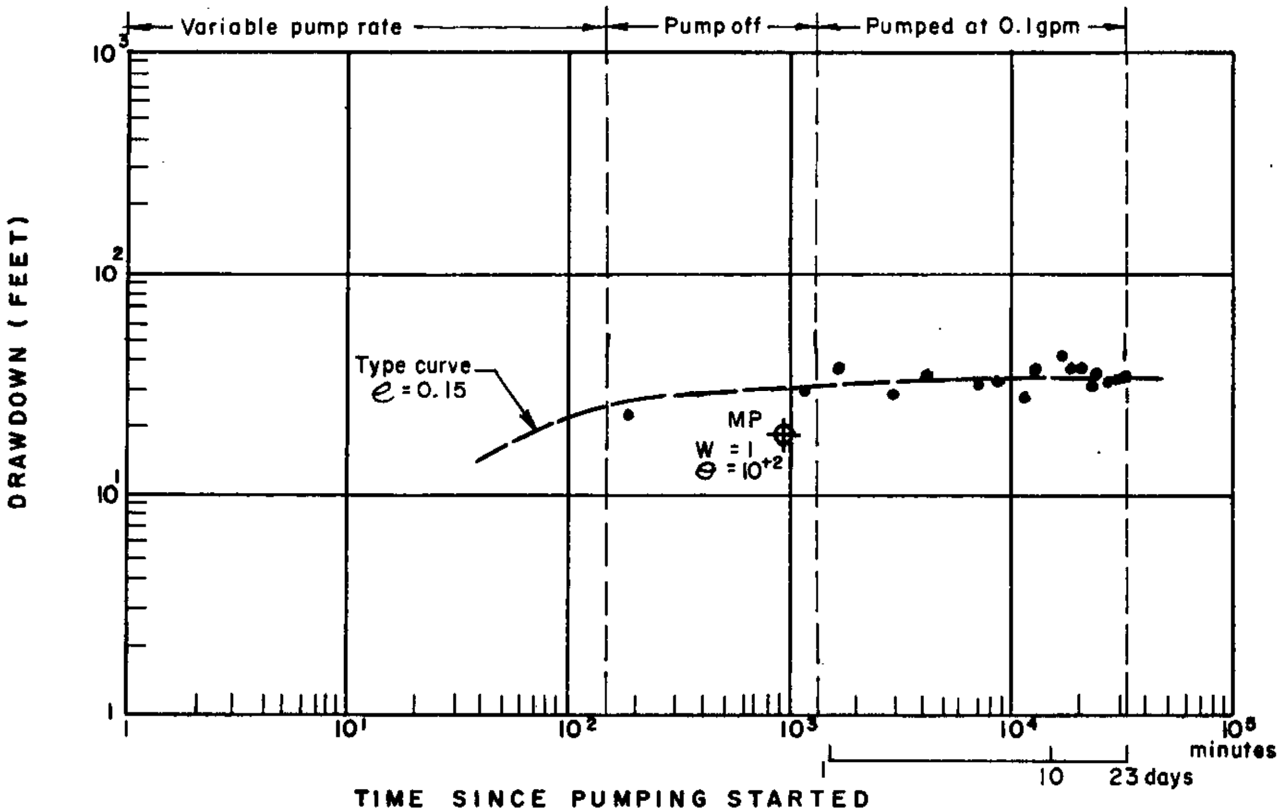
Datum elevation: 3179 a.s.l.
Elevation static water level: 3133 a.s.l.
Elevation of screened interval: 2788 to 2775 a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Aquifer Conditions: [✓] confined [ ] unconfined

Well depth: 400 feet
Well diameter: 8 inches
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm

Aquifer description: Coldwater Fm (Siltstone)
Aquifer thickness: 800 feet
Depth to pump suction: 370 feet
Type of test: [✓] constant rate [ ] step drawdown



Calculations:

$$T = \frac{114.6\,QW}{S} = \frac{114.6 \times 0.1 \times 1}{19} = 0.64 \text{ gpd/ft.}$$

$$S = \frac{Tt}{2693(r^2)\theta} = \frac{0.64 \times 920}{2693(249)^2 \times 100} = 3.5 \times 10^{-8}$$

Where:

W and θ are constant values for a given match point.

$$e = \frac{r}{h}\left[\frac{ky}{kh}\right]^{1/2}$$

h = thickness of aquifer.

Q = Average pumping rate (gpm)
S = Drawdown (feet)
r = Radius from pumped well (feet)
t = Time (minutes)
S = Storage coefficient
T = Transmissivity (gpd/ft.)

Golder Associates

Logged by: RAD

Project No. V763488

PUMP TEST DATA SUMMARY

Observations in RH 17-2
Sheet 1 of 2

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

DATE: Start: Sept. 22, 1976
Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [X] Pneumatic piezo. [ ] Unscreened well [ ] Standpipe piezo.

Datum point: Top of tube
Depth to static water level: 43 FT.
Screened/open hole interval: ____ to ____
Datum elevation: 3179 FT. a.s.l.
Elevation static water level: 3136 FT. a.s.l.
Elevation of screened interval: ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth: 400 feet
Well diameter: 8 inches
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm
Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description: Coldwater Fm (Siltstone)
Aquifer thickness: 800 feet
Depth to pump suction: 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Hr.	Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	9	00	0	43.2	102.5	3135.8			
	16	00	0	-	-	-			Pump started
	16	30	30	44.4	102	3134.6	8.4		
	19	00	180	60.5	95	3118.5	24.5		
23	11	30	1170	58.2	96	3120.8	22.2		
	19	30	1650	60.5	95	3118.5	24.5		
24	15	30	2850	60.5	95	3118.5	24.5		
25	13	30	4170	61.7	94.5	3117.3	25.7		
27	14	00	7080	59.4	95.5	3119.6	23.4		
28	14	30	8550	62.9	94	3116.1	26.9		
30	14	00	11400	61.7	94.5	3117.3	25.7		
1	15	45	12945	62.9	94	3116.1	26.9		
4	9	30	16890	69.8	91	3109.2	33.8		
5	13	00	18540	69.8	91	3109.2	33.8		
6	17	00	20220	69.8	91	3109.2	33.8		
8	11	00	22740	67.5	92	3111.5	31.5		
9	9	00	24060	69.8	91	3109.2	33.8		
10	15	30	25890	62.9	94	3116.1	26.9		
11	15	00	27300	67.5	92	3111.5	31.5		
13	14	00	30120	67.5	92	3111.5	31.5		
14	17	30	31770	67.5	92	3111.5	31.5		Pump stopped (19:11)
16	11	15		66.3	92.5	3112.7	30.3		
18	16	00		68.6	91.5	3110.4	32.6		
22	15	30		67.5	92	3111.5	31.5		
28	15	30		66.3	92.5	3112.7	30.3		

Golder Associates

Logged by: RD

Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

Observations in RH 17-2
Sheet 2 of 2

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
10	15	30		70.9	90.5	3108.1	34.9		

Golder Associates

Logged by RCD

Project No. V7634888

PUMP TEST DATA SUMMARY

Observations in RH 76-17-3
Sheet 1 of 2

PROJECT Hot Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: ☐ Screened well ☐ Unscreened well ☒ Pneumatic piezo. ☐ Standpipe piezo.

Datum point Top of tube
Depth to static water level 56.5 FT.
Screened/open hole interval ____ to ____

Datum elevation 3179 FT. a.s.l.
Elevation static water level 3122.5 FT. a.s.l.
Elevation of screened interval ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth 400 feet
Well diameter 8 inches
Pump type Electric Submersible
Final pumping rate 0.1 gpm

Aquifer Conditions: ☑ confined ☐ unconfined
Aquifer description Coldwater Fm (Siltstone)
Aquifer thickness 800 feet
Depth to pump suction 370 feet
Type of test: ☑ constant rate ☐ step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	9	00	0	57.4	47	3121.6			
	16	00	0	-	-	-	-		Pump started
	16	30	30	49.3	50.5	3129.7	-		
	19	00	180	66.7	43	3112.3	10.2		
23	11	30	1170	66.7	43	3112.3	10.2		
	19	30	1650	66.7	43	3112.3	10.2		
24	15	30	2850	67.8	42.5	3111.2	11.3		
25	13	30	4170	67.8	42.5	3111.2	11.3		
27	14	00	7080	66.7	43	3112.3	10.2		
28	14	30	8550	72.4	40.5	3106.6	15.9		
30	14	00	11400	72.4	40.5	3106.6	15.9		
1	15	45	12945	72.4	40.5	3106.6	15.9		
4	9	30	16890	71.3	41	3107.7	14.8		
5	13	00	18540	71.3	41	3107.7	14.8		
6	17	00	20220	71.3	41	3107.7	14.8		
8	11	00	22740	71.3	41	3107.7	14.8		
9	9	00	24060	74.8	39.5	3104.2	18.3		
10	15	30	25890	71.3	41	3107.7	14.8		
11	15	00	27300	71.3	41	3107.7	14.8		
13	14	00	30120	73.6	40	3105.4	17.1		
14	17	30	31770	69.0	42	3110.0	12.5		Pump stopped (19:11)
16	11	15		67.8	42.5	3111.2	11.3		
18	16	00		70.1	41.5	3108.9	13.6		
22	15	30		67.8	42.5	3111.2	11.3		
28	15	30		66.7	43	3112.3	10.2		

Golder Associates

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Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

Observations in RH 76-17-3
Sheet 2 of 2

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

Time			Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
Dy.	Hr.	Min.							
10	5	30		71.3	41	3107.7	14.8		

Golder Associates

Logged by RDB

Project No. V763488

PUMP TEST DATA SUMMARY

Observations in RH 76-18-1
Sheet 1 of 2

PROJECT: Hot Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

DATE: Start: Sept. 22, 1976
Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [X] Pneumatic piezo. [ ] Standpipe piezo.

Datum point: Top of tube
Depth to static water level: 34.7 FT.
Screened/open hole interval ____ to ____
Datum elevation: 3195 FT. a.s.l.
Elevation static water level: 3160.3 FT. a.s.l.
Elevation of screened interval ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description: Coldwater Fm (Siltstone)
Aquifer thickness: 800 feet
Depth to pump suction: 370 feet

Well depth: 400 feet
Well diameter: 8 inches
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm

Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	9	00	0	32.6	156	3162.4			
	16	00	0	-	-	-	-		Pump started
	16	30	30	46.5	150	3198.5	11.8		
	19	00	180	56.9	145.5	3138.1	22.2		
23	11	30	1170	63.8	142.5	3131.2	29.1		
	19	30	1650	69.6	140	3125.4	34.9		
24	15	30	2850	63.8	142.5	3131.2	29.1		
25	13	30	4170	66.1	141.5	3128.9	31.4		
27	14	00	7080	62.7	143	3132.3	28.0		
28	14	30	8550	62.7	143	3132.3	28.0		
30	14	00	11400	62.7	143	3132.3	28.0		
1	15	45	12945	69.6	140	3125.4	34.9		
4	9	30	16890	76.5	137	3118.5	41.8		
5	13	00	18540	74.2	138	3120.8	39.5		
6	17	00	20220	71.9	139	3123.1	37.2		
8	11	00	22740	76.5	137	3118.5	41.8		
9	9	00	24060	74.2	138	3120.8	39.5		
10	15	30	25890	71.9	139	3123.1	37.2		
11	15	00	27300	74.2	138	3120.8	39.5		
13	14	00	30120	70.8	139.5	3124.2	36.1		
14	17	30	31770	74.2	138	3120.8	39.5		Pump stopped (19:11)
16	11	15		73.1	138.5	3121.9	38.4		
18	16	00		74.2	138	3120.8	39.5		
22	15	30		69.6	140	3125.4	34.9		
28	15	30		69.6	140	3125.4	34.9		

Golder Associates

Logged by: [illegible]

Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT Hat Creek Coal
Location Coche Creek, B.C.
Pumped Well RH 76-19

Observations in RH 76-18-1
Sheet 2 of 2

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
10	15	30		71.9	139	3123.1	37.2		

Golder Associates

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Project No. V76348B

PUMP TEST DATA SUMMARY

Observations in RH 76-18-2
Sheet 1 of 3

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

DATE: Start: Sept. 22, 1976 — Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [X] Pneumatic piezo. [ ] Standpipe piezo.

Datum point: Top of tube
Depth to static water level: 25.5 FT.
Screened/open hole interval: ___ to ___
Datum elevation: 3195 FT. a.s.l.
Elevation static water level: 3169.5 FT. a.s.l.
Elevation of screened interval: ___ to ___ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth: 400 feet
Well diameter: 8 inches
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm
Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description: Coldwater Fm (Siltstone)
Aquifer thickness: 800 feet
Depth to pump suction: 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i.)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	9	00	0	20.9	118	3174.1			
	16	00	0	-	-	-	-		Pump started
	16	30	30	10.5	122.5	3184.5	-		
	19	00	180	44.0	108	3151.0	18.5		
23	11	30	1170	47.5	106.5	3147.5	22		
	19	30	1650	49.8	105.5	3145.2	24.3		
24	15	30	2850	48.4	110	3146.6	22.9		
25	13	30	4170	46.3	107	3148.7	20.8		
27	14	00	7080	40.6	109.5	3154.4	15.1		
28	14	30	8550	41.7	109	3153.3	16.2		
30	14	00	11400	46.3	107	3148.7	20.8		
1	15	45	12945	48.4	106	3146.4	23.1		
4	9	30	16890	53.3	104	3141.7	27.8		
5	13	00	18540	50.9	105	3144.1	25.4		
6	17	00	20220	50.9	105	3144.1	25.4		
8	11	00	22740	53.3	104	3141.7	27.8		
9	9	00	24060	52.1	104.5	3142.9	26.6		
10	15	30	25890	50.9	105	3144.1	25.4		
11	15	00	27300	52.1	104.5	3142.9	26.6		
13	14	00	30120	50.9	105	3144.1	25.4		
14	17	30	31770	53.3	104	3141.7	27.8		Pump stopped (19:11)
16	11	15		50.9	105	3144.1	25.4		
18	16	00		50.9	105	3144.1	25.4		
22	15	30		50.9	105	3144.1	25.4		
28	15	30		50.9	105	3144.1	25.4		

Golder Associates

Logged by: [illegible]

Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

Observations in RH 76-18-2
Sheet 2 of 3

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
10	15	30		57.9	102	3137.1	32.4		

Golder Associates

Logged by RAS

Project No. V7634BB

PUMP TEST DATA SUMMARY

Observations in RH 76-18-2
Sheet 3 of 3

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

DATE: Start: Sept. 22, 1976
Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [x] Pneumatic piezo. [ ] Standpipe piezo.

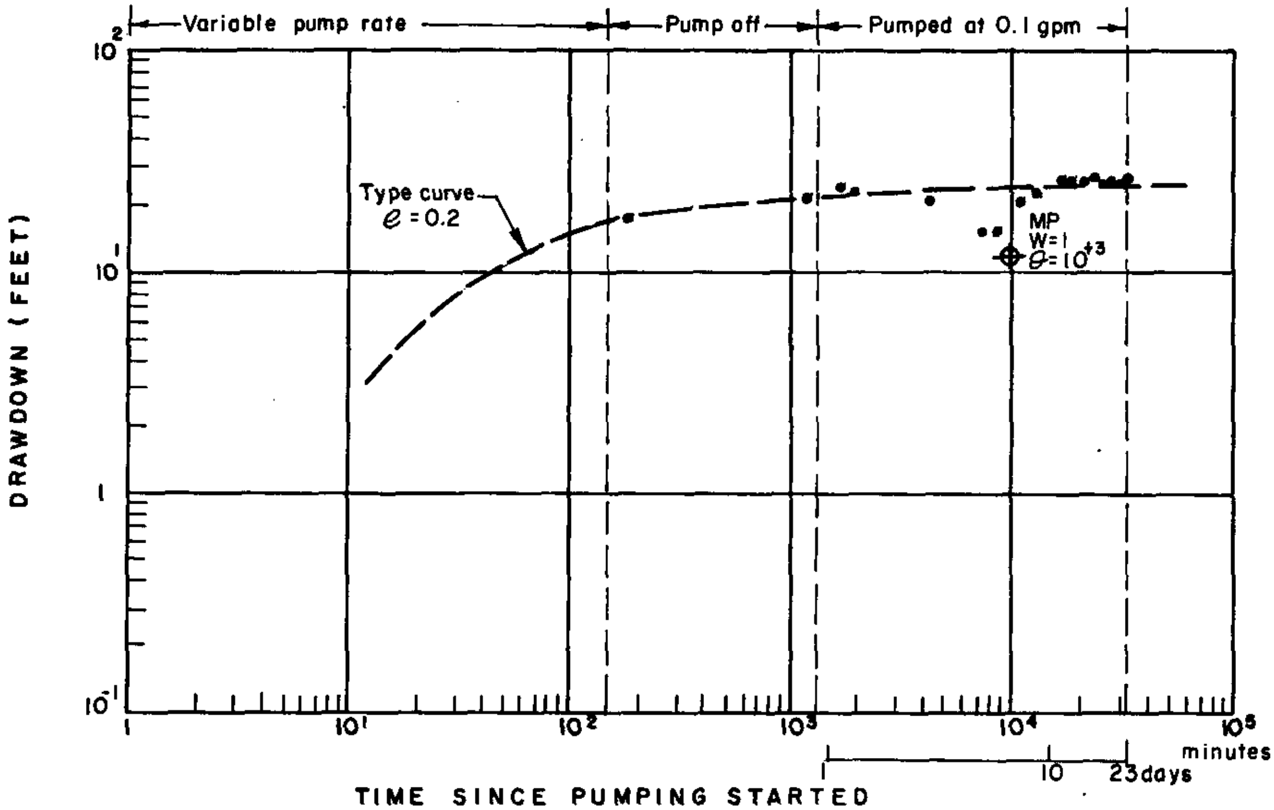
Datum point: Top of tube
Depth to static water level: 21 ft.
Screened/open hole interval: 282 to 285 ft.

Datum elevation: 3195 a.s.l.
Elevation static water level: 3174 a.s.l.
Elevation of screened interval: 2913 to 2910 a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description: Coldwater Fm (Siltstone)
Aquifer thickness: 800 feet
Depth to pump suction: 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Well depth: 400 feet
Well diameter: 8 inches
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm



Calculations:

$$T = \frac{114.6\,QW}{S} = \frac{114.6 \times 0.1 \times 1}{12} = 0.96 \text{ gpd/ft.}$$

$$S = \frac{Tt}{2693(r^2)\theta} = \frac{0.96 \times 10^{+4}}{2693(357)^2 \times 10^{+3}} = 2.8 \times 10^{-8}$$

Where: W and θ are constant values for a given match point.

$$e = \frac{r}{h}\left[\frac{k_v}{k_h}\right]^{1/2}$$

h = thickness of aquifer.

Q = Average pumping rate (gpm)
S = Drawdown (feet)
r = Radius from pumped well (feet)
t = Time (minutes)
S = Storage coefficient
T = Transmissivity (gpd/ft.)

Golder Associates

Logged by: RAB

Project No. V763488

PUMP TEST DATA SUMMARY

Observations in RH 76-19-3
Sheet 1 of 2

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [x] Pneumatic piezo. [ ] Standpipe piezo.

Datum point Top of tube
Depth to static water level 14 FT.
Screened/open hole interval ____ to ____
Datum elevation 3195 FT. a.s.l.
Elevation static water level 3181 FT. a.s.l.
Elevation of screened interval ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description Coldwater Fm (Siltstone)
Aquifer thickness 800 feet
Depth to pump suction 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Well depth 400 feet
Well diameter 8 inches
Pump type Electric Submersible
Final pumping rate 0.1 gpm

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	9	00	0	6.0	80.5	3189	-		
	16	00	0		-	-	-		Pump started
	16	30	30	14.1	77	3180.9	.1		
	19	00	180	24.5	72.5	3170.5	10.5		
23	11	30	1170	31.5	69.5	3163.5	17.5		
	19	30	1650	28	71	3167.0	14.0		
24	15	30	2850	26.8	71.5	3168.2	12.8		
25	13	30	4170	31.5	69.5	3163.5	17.5		
27	14	00	7080	28	71	3167.0	14.0		
28	14	30	8550	28	71	3167.0	14.0		
30	14	00	11400	36.1	67.5	3158.9	22.1		
1	15	45	12945	36.1	67.5	3158.9	22.1		
4	9	30	16890	39.5	66	3155.5	25.5		
5	13	00	18540	41.8	65	3153.2	27.8		
6	17	00	20220	39.5	66	3155.5	25.5		
8	11	00	22740	39.5	66	3155.5	25.5		
9	9	00	24060	40.3	65.5	3154.7	26.3		
10	15	30	25890	39.5	66	3155.5	25.5		
11	15	00	27300	39.5	66	3155.5	25.5		
13	14	00	30120	37.2	67	3157.8	23.2		
14	17	30	31770	40.3	65.5	3154.3	26.7		Pump stopped (19:11)
16	11	15		39.5	66	3155.5	25.5		
18	16	00		39.5	66	3155.5	25.5		
22	15	30		38.4	66.5	3156.6	24.4		
28	15	30		37.2	67	3157.8	23.2		

Logged by ____

Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT HAT CREEK COAL
Location CACHE CREEK, B.C.
Pumped Well RH 76-19

Observations in RH 76-18-3
Sheet 2 of 2

DATE: Start SEPT. 22, 1976
Finish OCT. 14, 1976

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
10	15	30		44.2	64	3150.8	30.2		

Golder Associates

Logged by RCB

Project No. V763488

PUMP TEST DATA SUMMARY

Observations in RH 76-19
Sheet 1 of 6

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [X] Screened well [ ] Unscreened well [ ] Pneumatic piezo. [ ] Standpipe piezo.

Datum point Top of tube
Depth to static water level 89.3 FT.
Screened/open hole interval ____ to ____

Datum elevation 3183.5 FT. a.s.l.
Elevation static water level 3094.2 FT. a.s.l.
Elevation of screened interval ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth 400 feet
Well diameter 8 inches
Pump type Electric Submersible
Final pumping rate 0.1 gpm

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description Coldwater Fm (Siltstone)
Aquifer thickness 800 feet
Depth to pump suction 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	16	00	0	89.3		3094.2	0	1.0	W.L. probe on the blink
		½	½	-		-	-	1.0	W.L. probe on the blink
		1	1	-			-	1.0	
		1½	1½	93.4		3090.1	4.1	1.0	
		2	2	90.2		3093.3	0.9	1.0	
		2½	2½	90.3		3093.2	1.0	1.0	
		3	3	90.4		3093.1	1.1	1.0	
		3½	3½	90.5		3093.0	1.2	1.0	
		4	4	90.7		3092.8	1.4	1.0	Q varied from 0.9-1.1
		4½	4½	90.9		3092.6	1.6	1.0	due to siltation in valve
		5	5	91.0		3092.5	1.7	1.0	
		6	6	91.3		3092.2	2.0	1.0	
		7	7	91.5		3092.0	2.2	1.0	
		8	8	-		-	-	1.0	W.L. probe problems
		9	9	92.3		3091.2	3.0	1.0	
		10	10	92.5		3091.0	3.2	1.0	
		12	12	93.2		3090.3	3.9	1.0	
		14	14	93.7		3089.8	4.4	1.0	
		16	16	94.2		3089.3	4.9	1.0	Water temp = 9.5°C
		18	18	94.7		3088.8	5.4	1.0	
		20	20	95.2		3088.3	5.9	1.0	
		25	25	96.7		3086.8	7.4	1.0	
		30	30	98.4		3085.1	9.1	1.0	
		45	45	102.6		3080.9	13.3	1.0	
22	17	0	60	-		-	-	1.0	Generator problems

Golder Associates

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Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT HAT CREEK COAL
Location CACHE CREEK, B.C.
Pumped Well RH 76-19

Observations in RH 76-19

DATE: Start SEPT. 22/76
Finish OCT. 14/76

Time Dy.	Hr.	Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	17	30	90	105.8		3077.7	16.5	1.0	Conductivity = 1300 micro-
	18	0	120	111.2		3072.3	21.9	1.0	mhos/cm.
	18	30	150	113.9		3069.6	24.6	1.0	
	19	00	180	-		-	-	1.0	Test discontinued due to
									generator problems
23	13	30½	1290½	105.1		3078.4	15.8	1.0	Pumping resumed.
		31	1291	105.3		3078.2	16.0	1.0	Water - creamy, silty
		31½	1291½	105.4		3078.1	16.1	1.0	
		32	1292	105.6		3077.9	16.3	1.0	
		32½	1292½	105.6		3077.9	16.3	1.0	
		33	1293	105.7		3077.8	16.4	1.0	
		33½	1293½	105.8		3077.7	16.5	1.0	
		34	1294	105.9		3077.6	16.6	1.0	
		34½	1294½	106.0		3077.5	16.7	1.0	
		35	1295	106.1		3077.4	16.8	1.0	
		36	1296	106.3		3077.2	17.0	1.0	
		37	1297	106.5		3077.0	17.2	1.0	
		38	1298	106.7		3076.8	17.4	1.0	
		39	1299	106.9		3076.6	17.6	1.0	
		40	1300	107.2		3076.3	17.9	1.0	
		42	1302	107.7		3075.8	18.4	1.0	
		44	1304	108.0		3075.5	18.7	1.0	
		46	1306	108.4		3075.1	19.1	1.0	
		48	1308	108.8		3074.7	19.5	1.0	
		50	1310	109.4		3074.1	20.1	1.0	
		55	1315	110.5		3073.0	21.2	1.0	
	14	0	1320	112.1		3071.4	22.8	1.0	
		10	1330	114.2		3069.3	24.9	1.0	
		20	1340	116.9		3066.6	27.6	1.0	
		30	1350	-		-	-	1.0	
		50	1370	120.0		3063.5	30.7	1.0	
	15	10	1390	122.5		3061.0	33.2	1.0	
23		35	1415	128.2		3055.3	38.9	1.0	

Golder Associates

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Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT HAT CREEK COAL
Location CACHE CREEK, B.C.
Pumped Well RH 76-19

Observations in RH 76-19
Sheet 3 of 6

DATE: Start SEPT. 22/76
Finish OCT. 14/76

Time Dy.	Hr.	Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
23	16	0	1440	131.5		3052.0	42.2	1.0	Water colour - very silty
		40	1480	137.4		3046.1	48.1	1.0	dirty appearance
	17	30	1530	143.4		3040.1	54.1	1.0	
	18	20	1580	145.3		3038.2	56.0	1.0	
	19	10	1630	147.2		3036.3	57.9	1.0	
	20	0	1680	154.3		3029.2	65.0	1.0	
	20	50	1730	-		-	-	1.0	
	21	40	1780	159.9		3023.6	70.6	1.0	
	22	30	1830	163.2		3020.3	73.9	1.0	
	23	20	1880	168.2		3015.3	78.9	1.0	
24	0	10	1930	176.7		3006.8	87.4	1.0	
	1	0	1980	182.5		3001.0	93.2	1.0	
	1	50	2030	189.6		2993.9	100.3	1.0	
	4	30	2190	-		-	-	1.0	
	5	20	2240	214.6		2968.9	125.3	1.0	
	7	50	2390	242.8		2940.7	153.5	1.0	
	8	40	2440	253.6		2929.9	164.3	1.0	
	9	30	2490	260.3		2923.2	171.0	1.0	
	10	20	2540	269.8		2913.7	180.5	1.0	
	11	10	2590	278.7		2904.8	189.4	1.0	
	12	0	2640	284.3		2899.2	195.0	1.0	
	12	50	2690	290.2		2893.3	200.9	1.0	
	13	40	2740	298.4		2885.1	209.1	1.0	
	14	30	2790	302.9		2880.6	213.6	1.0	
	15	20	2840	307.8		2875.7	218.5	1.0	
	16	10	2890	310.8		2872.7	221.5	½	Flow adjusted to ½ gpm.
	17	0	2940	312.4		2871.1	223.1	½	
	17	50	2990	317.4		2866.1	228.1	½	
	18	40	3040	-		-	-	½	Adjustment to flow
	19	30	3090	317.2		2866.3	227.9	½	
	20	20	3140	318.8		2864.7	229.5	½	
	21	10	3190	320.6		2862.9	231.3	½	
24	22	00	3240	321.9		2861.6	232.6	½	

Golder Associates

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PUMP TEST DATA SUMMARY

Project No. V7634AB

PROJECT: HAT CREEK COAL
Location: CACHE CREEK, B.C.
Pumped Well: RH 76-19

Observations in RH 76-19
Sheet 4 of 6

DATE: Start SEPT. 22/76
Finish OCT. 14/76

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
24	22	50	3290	322.9		2860.6	233.6	½	
	23	40	3340	324.5		2859.0	235.2	½	
25	0	30	3390	326.0		2857.5	236.7	½	
	1	20	3440	327.2		2856.3	237.9	½	
	2	10	3490	329.5		2854.0	240.2	½	
	3	00	3540	330.4		2853.1	241.1	½	
	3	50	3590	331.4		2852.1	242.1	½	
	4	40	3640	331.4		2852.1	242.1	½	
	5	30	3690	332.6		2850.9	243.3	½	
	6	20	3740	334.3		2849.2	245.0	½	Adjustment of flow
	7	10	3790	336.0		2847.5	246.7	½	
	8	00	3840	338.0		2845.5	248.7	½	
	10	0	3960	335.4		2848.1	246.1	½	
	11	0	4020	336.7		2846.8	247.4	½	Water clearing; still silty
	11	50	4070	336.5		2847.0	247.2	½	
	15	00	4260	337.3		2846.2	248.0	20 oz/m.	Flow adjusted to 20 oz/min.
	17	00	4380	339.0		2844.5	249.7	20 oz/m.	
	18	00	4440	337.5		2846.0	248.2	4 oz/m.	
25	21	00	4620	334.5		2849.0	245.2	10 oz/m.	Flow adjusted to 10 oz/mon.
26	2	00	4920	325.3		2858.2	236.0	10 oz/m.	
	6	00	5160	326.1		2857.4	236.8	-	Difficult to keep valve
	12	00	5520	320.2		2863.3	230.9	20 oz/m.	unsilted, therefore causing
	16	00	5760	315.7		2867.8	226.4	15 oz/m.	uneven Q rates
27	8	00	6720	313.0		2870.5	223.7	15 oz/m.	
	14	00	7080	313.8		2869.7	224.5	15 oz/m.	Water clearer, less silty
	19	00	7280	314.0		2869.5	224.7	15 oz/m.	
28	8	30	8190	307.9		2875.6	218.6	10 oz/m.	Temp. = 13°C, Cond. = 1670
	14	00	8520	316.3		2867.2	227.0	20 oz/m.	Water - light grey, br.
29	8	30	9630	318.7		2864.8	229.4	15 oz/m.	
	19	00	10260	320.9		2862.6	231.6	15 oz/m.	
30	8	30	11070	320.7		2862.8	231.4	15 oz/m.	
	18	30	11670	325.7		2857.8	236.4	15 oz/m.	
1	8	30	12510	329.3		2854.2	240.0	15 oz/m.	Water fairly clear

Golder Associates

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Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT HAT CREEK COAL
Location CACHE CREEK, B.C.
Pumped Well RH 76-19

Observations in RH 76-19
Sheet 5 of 6

DATE: Start SEPT. 22/76
Finish OCT. 14/76

Time Dy.	Hr.	Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
1	15	45	12945	327.7		2855.8	238.4	10 oz/m.	Rained at night
2	8	30	13950	321.7		2861.8	232.4	7 oz/m.	When first meas. = 7 oz/m. Valve shaken-Q inc. to 15
4	10	00	16920	313.3		2870.2	224.0	12 oz/m.	Rained at night
5	13	00	18540	314.9		2868.6	225.6	10 oz/m.	
6	17	30	20250	318.8		2864.7	229.5	11 oz/m.	Water fairly clear
8	10	00	22680	324.0		2859.5	234.7	10 oz/m.	
9	10	00	24120	323.0		2860.5	233.7	10 oz/m.	
10	15	00	25860	324.0		2859.5	234.7	10 oz/m.	
11	15	00	27300	322.0		2861.5	232.7	10 oz/m.	
12	14	30	28710	318.0		2865.5	228.7	9 oz/m.	
13	14	00	30120	320.0		2863.5	230.7	10 oz/m.	
14	18	00	31800	237.4		2946.1	148.1	4 oz/m.	Low Q, due to silting
14	19	11	31871	246.5		2937.0	157.2	~1 GPM	PUMP SHUT OFF
			t'(min)						
14	19	11½	½	-		-	-		RECOVERY
	19	12	1	246.4		2937.1	157.1		
		12½	1½	246.3		2937.2	157.0		
		13	2	246.3		2937.2	157.0		
		13½	2½	246.3		2937.2	157.0		
		14	3	246.2		2937.3	156.9		
		14½	3½	246.2		2937.3	156.9		
		15	4	246.2		2937.3	156.9		
		15½	4½	246.2		2937.3	156.9		
		16	5	246.2		2937.3	156.9		
		17	6	-		-	-		
		18	7	246.1		2937.4	156.8		
		19	8	246.1		2937.4	156.8		
		20	9	246.1		2937.4	156.8		
		21	10	246.1		2937.4	156.8		
		23	12	246.0		2937.5	156.7		
		25	14	246.0		2937.5	156.7		
		27	16	245.9		2937.6	156.6		
		29	18	245.9		2937.6	156.6		

Logged by [signature]

Project No. V76348B

PUMP TEST DATA SUMMARY

PROJECT HAT CREEK COAL
Location CACHE CREEK, B.C.
Pumped Well RH 76-19

Observations in RH 76-19
Sheet 6 of 6

DATE: Start SEPT. 22/76
Finish OCT. 14/76

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
14	19	31	20	245.9		2937.6	156.6		RECOVERY
		36	25	245.8		2937.7	156.6		
		41	30	245.6		2937.9	156.3		
		46	35	245.5		2938.0	156.2		
		51	40	245.4		2938.1	156.1		
		01	50	245.2		2938.3	155.9		
		11	60	244.9		2938.6	155.6		
		26	75	244.6		2938.9	155.3		
		51	100	243.6		2939.9	154.3		
	21	41	150	241.8		2941.7	152.5		
	22	31	200	240.8		2942.7	151.5		
	23	21	250	239.0		2943.6	150.6		
15	0	11	300	239.0		2944.5	149.7		
	8	31	800	228.9		2954.6	139.6		
	11	51	1000	227.9		2955.6	138.6		Pump Removed
	18	31	1400	219.6		2963.9	130.3		
16	8	41	2250	204.4		2979.1	115.1		
	15	21	2650	198.7		2984.8	109.4		
18	16	01	5570	163.4		3020.1	74.1		
22	17	11	11400	114.2		3069.3	24.9		After reading - added water
	18	51	11500	97.8		3085.7	8.5		
28	15	21	19930	91.8		3091.7	2.5		

Golder Associates

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Project No. V7634ABB

PUMP TEST DATA SUMMARY

Observations in DDH 76-144
Sheet 1 of 1

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

DATE: Start: Sept. 22, 1976 Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [ ] Pneumatic piezo. [X] Standpipe piezo.

Datum point: Top of tube
Depth to static water level: 47.9 FT.
Screened/open hole interval: ____ to ____
Datum elevation: 3137.1 FT. a.s.l.
Elevation static water level: 3085 FT. a.s.l.
Elevation of screened interval: ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth: 400 feet
Well diameter: 8 inches
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm
Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description: Coldwater Fm (Siltstone)
Aquifer thickness: 800 feet
Depth to pump suction: 370 feet
Type of test: [✓] constant rate [ ] step drawdown

	Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
S	22	15	00	0	53.1		3084			
		16	00	0	-		-	-		Pump started
	23	11	30	1170	54.6		3082.5	2.5		
	24	15	30	2850	52.9		3084.2	0.8		
	25	14	00	4200	53.1		3084	1.0		
	28	14	30	8550	53.7		3083.4	1.6		
	30	14	00	11400	54.3		2082.8	2.2		
O	4	9	30	16890	55.9		3081.2	3.8		
	6	17	00	20220	56.3		3080.8	4.2		
	9	10	00	24120	57.0		3080.1	4.9		
	11	15	00	27300	57.0		3080.1	4.9		
	14	19	11	31871	-		-	-		Pump stopped
	16	11	00		57.3		3079.8	5.2		
	18	15	20		-		-			
	22	15	30		58.1		3079	6.0		
	28	15	30		-		-			
N	10	15	30		60.3		3076.8	8.2		

Golder Associates

Logged by: RMO

Project No. V7634888

PUMP TEST DATA SUMMARY

Observations in DDH 76-145
Sheet 1 of 1

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

DATE: Start: Sept. 22, 1976
Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [X] Unscreened well [ ] Pneumatic piezo. [ ] Standpipe piezo.

Datum point: Top of tube
Depth to static water level: 45.5 FT.
Screened/open hole interval ____ to ____
Datum elevation: 3196.5 FT. a. s. l.
Elevation static water level: 3151 FT. a. s. l.
Elevation of screened interval ____ to ____ a. s. l.

DATA ON PUMPED WELL AND AQUIFER:

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description: Coldwater Fm (Siltstone)
Well depth: 400 feet
Well diameter: 8 inches
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm
Aquifer thickness: 800 feet
Depth to pump suction: 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	16	00	0		-		-		Pump started
23	11	30	1170	46.7		3149.8	1.2		
24	15	30	2850	46.4		3150.1	0.9		
24	14	00	4200	46.3		3150.2	0.8		
28	14	30	8550	46.6		3149.9	1.1		
30	14	00	11400	47.4		3149.1	1.9		
4	9	30	16890	46.8		3149.7	1.3		
6	17	00	20220	45.8		3150.7	0.3		
14	19	11	31871	-					Pump stopped
16	11	00		47.5		3149.0	2.0		
22	15	30		48.8		3147.7	3.3		
28	15	30		48.8		3147.7	3.3		

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Project No. V7634BB

PUMP TEST DATA SUMMARY

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

Observations in DDH 76-149-1
Sheet 1 of 2

DATE: Start: Sept. 22, 1976
Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [ ] Pneumatic piezo. [X] Standpipe piezo.

Datum point: Top of tube
Depth to static water level: 65 FT.
Screened/open hole interval: ____ to ____
Datum elevation: 3270 FT. a.s.l.
Elevation static water level: 3205 FT. a.s.l.
Elevation of screened interval: ____ to ____ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth: 400 feet
Well diameter: 8 inches
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description: Coldwater Fm (Siltstone)
Aquifer thickness: 800 feet
Depth to pump suction: 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	15	00	0	67.4		3202.6	-		
	16	00	0	-		-	-		Pump started
23	11	30	1170	73.5		3146.5	8.5		
24	15	30	2850	74.1		3195.9	9.1		
25	14	00	4200	74.5		3195.5	9.5		
28	14	30	8550	75.5		3194.5	10.5		
30	14	00	11400	76.7		3193.3	11.7		
4	9	30	16890	77.7		3192.3	12.7		
6	17	00	20220	78.3		3191.7	13.3		
9	10	00	24120	80.0		3190	15.0		
11	15	00	27300	80.0		3190	15.0		
14	19	11	31871	-		-	-		Pump stopped
16	11	00		80.8		3189.2	15.8		
18	15	20		81.6		3188.4	16.6		
22	15	30		81.6		3188.4	16.6		
28	15	30							
10	15	30							

Logged by: [illegible]

Project No. V7634BB

PUMP TEST DATA SUMMARY

Observations in DDH 76-149-1
Sheet 2 of 2

PROJECT Hat Creek Coal
Location Cache Creek, B.C.
Pumped Well RH 76-19

DATE: Start Sept. 22, 1976
Finish Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [ ] Pneumatic piezo. [x] Standpipe piezo.

Datum point Top of tube
Depth to static water level 65 ft.
Screened/open hole interval 115 to 120

Datum elevation 3270 ft a. s. l.
Elevation static water level 3205 a. s. l.
Elevation of screened interval 3155 to 3150 a. s. l.

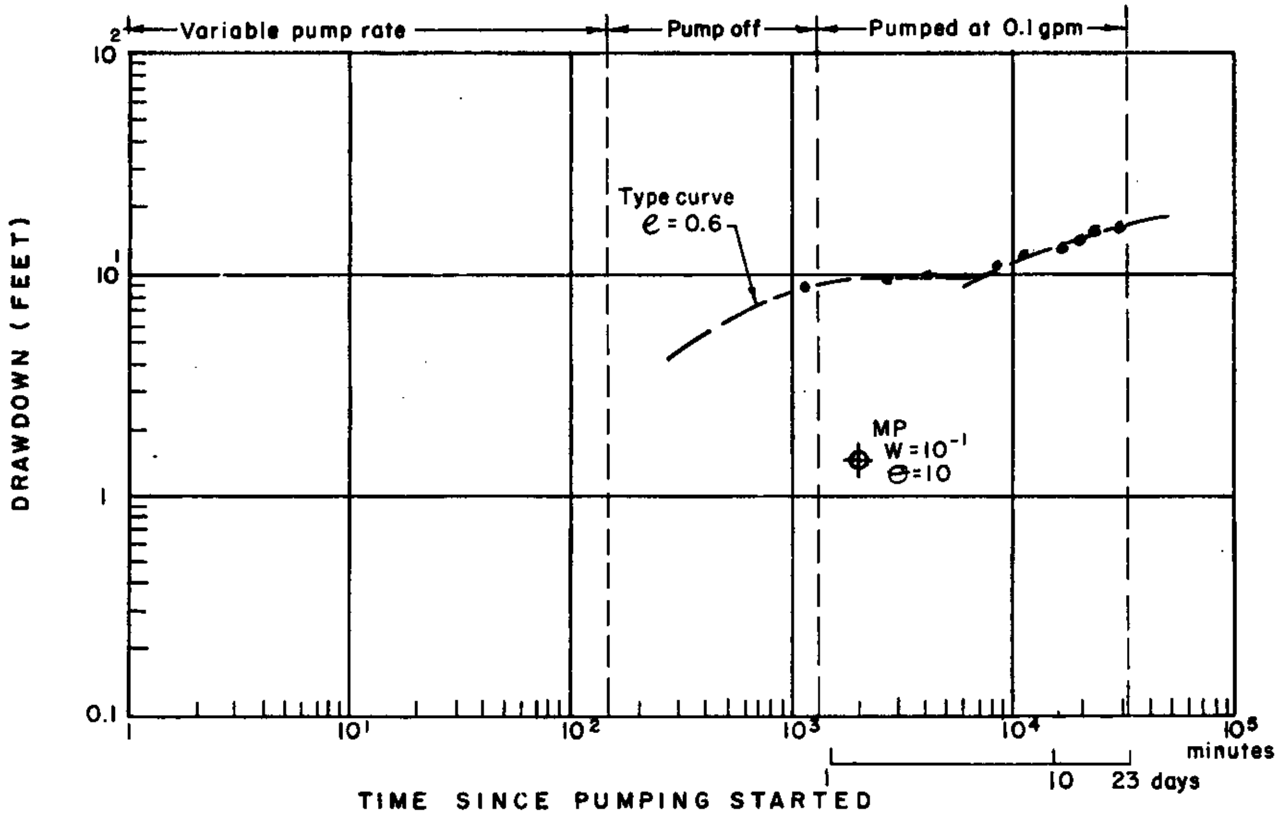
DATA ON PUMPED WELL AND AQUIFER:

Aquifer Conditions: [✓] confined [ ] unconfined

Well depth 400 feet
Well diameter 8 inches
Pump type Electric Submersible
Final pumping rate 0.1 gpm

Aquifer description Coldwater Fm (Siltstone)
Aquifer thickness 800 feet
Depth to pump suction 370 feet

Type of test: [✓] constant rate [ ] step drawdown



Calculations:

$$T = \frac{114.6\,QW}{S} = \frac{114.6 \times 0.1 \times 0.1}{2.2} = 0.5 \quad \text{gpd/ft.}$$

$$S = \frac{Tt}{2693(r^2)\Theta} = \frac{0.5 \times 2.7 \times 10^{+4}}{2693(1080)^2 \times 10} = 4.3 \times 10^{-7}$$

Where: W and Θ are constant values for a given match point.

$$e = \frac{r}{h}\left[\frac{k_v}{k_h}\right]^{1/2}$$

h = thickness of aquifer.

Q = Average pumping rate (gpm)
S = Drawdown (feet)
r = Radius from pumped well (feet)
t = Time (minutes)
S = Storage coefficient
T = Transmissivity (gpd/ft.)

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Project No. V763488

PUMP TEST DATA SUMMARY

Observations in DDH 76-149-2
Sheet 1 of 2

PROJECT: Hat Creek Coal
Location: Cache Creek, B.C.
Pumped Well: RH 76-19

DATE: Start: Sept. 22, 1976
Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

Type: [ ] Screened well [ ] Unscreened well [x] Pneumatic piezo. [ ] Standpipe piezo.

Datum point: Top of tube
Depth to static water level: 70 FT.
Screened/open hole interval: ___ to ___
Datum elevation: 3270 FT. a.s.l.
Elevation static water level: 3200 FT. a.s.l.
Elevation of screened interval: ___ to ___ a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Well depth: 400 feet
Well diameter: 8 inches
Pump type: Electric Submersible
Final pumping rate: 0.1 gpm

Aquifer Conditions: [✓] confined [ ] unconfined
Aquifer description: Coldwater Fm (Siltstone)
Aquifer thickness: 800 feet
Depth to pump suction: 370 feet
Type of test: [✓] constant rate [ ] step drawdown

Time Dy.	Time Hr.	Time Min.	Elapsed Time "t" (mins.)	Depth to Water (ft.)	Pressure (Pneumatic piezometers only) (p.s.i)	Elevation of Water (ft.) a.s.l.	Drawdown (ft.)	Pump Rate Q (i.g.p.m)	Remarks
22	15	00	0	79.1	19	3190.9	-		
	16	00	0	-	-	-	-		Pump started
23	11	30	1170	83.7	17	3186.3	13.7		
24	15	30	2850	84.9	16.5	3185.1	14.9		
25	14	00	4200	93	13	3177	23.0		
28	14	30	8550	90.7	14	3179.3	20.7		
30	14	00	11400	95.3	12	3174.7	25.3		
4	9	30	16890	97.6	11	3172.4	27.6		
6	17	00	20220	97.6	11	3172.4	27.6		
9	10	00	24120	94.1	12.5	3175.9	24.1		
11	15	00	27300	95.3	12	3174.7	25.3		
14	19	11	31871	-	-	-	-		Pump stopped
16	11	00		99.9	10	3170.1	29.9		
18	15	20		99.9	10	3170.1	29.9		
22	15	30		96.5	11.5	3173.5	26.5		
28	15	30			-	-	-		
10	15	30		53.7	30	3216.3	-		

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Project No. V763408

PUMP TEST DATA SUMMARY

PROJECT: Hat Creek Coal	Observations in DDH 76-149-2
Location: Cache Creek, B.C.	Sheet 2 of 2
Pumped Well: RH 76-19	DATE: Start: Sept. 22, 1976; Finish: Oct. 14, 1976

DATA ON OBSERVATION POINT:

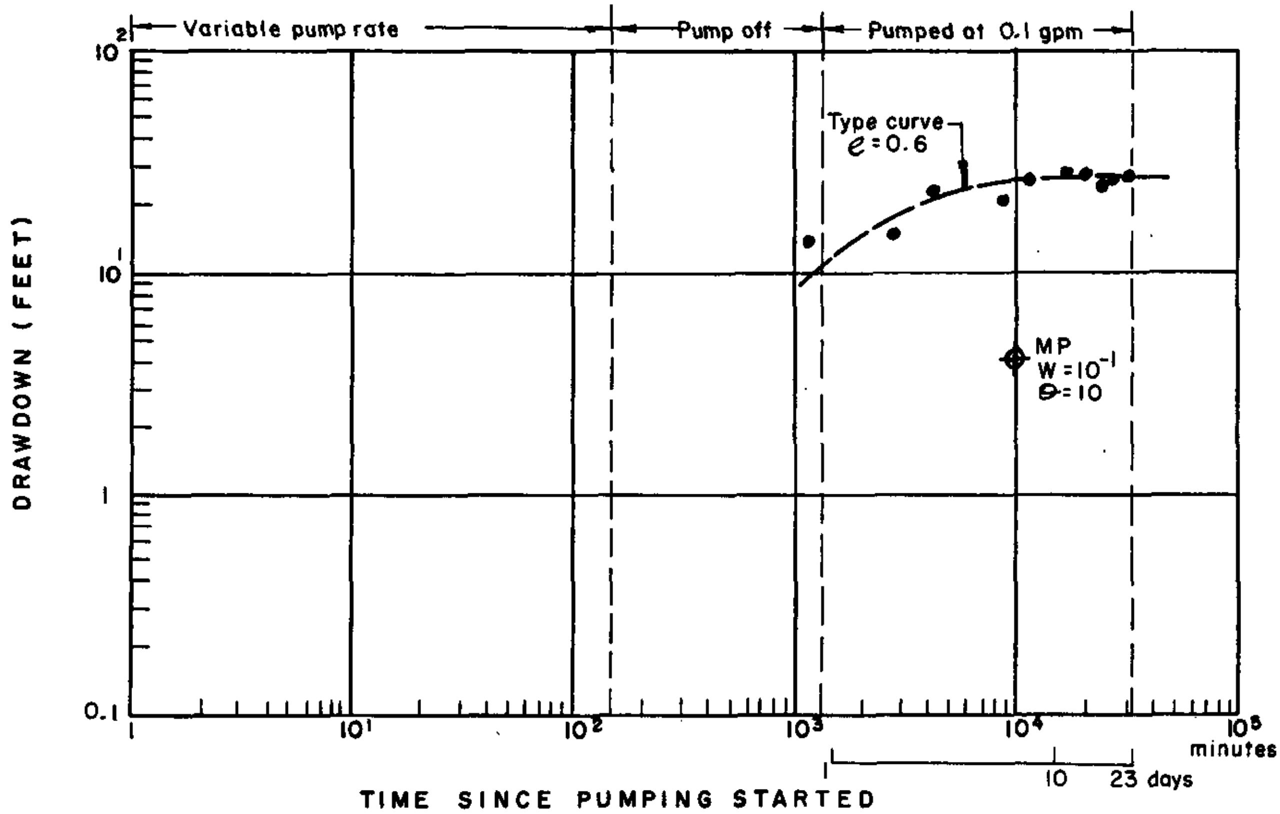
Type: [ ] Screened well [ ] Unscreened well [X] Pneumatic piezo. [ ] Standpipe piezo.

Datum point: Top of tube	Datum elevation: 3270 a.s.l.
Depth to static water level: 70	Elevation static water level: 3200 a.s.l.
Screened/open hole interval: 115 to 120	Elevation of screened interval: 3155 to 3150 a.s.l.

DATA ON PUMPED WELL AND AQUIFER:

Aquifer Conditions: [✓] confined [ ] unconfined

Well depth: 400 feet	Aquifer description: Coldwater Fm (Siltstone)
Well diameter: 8 inches	Aquifer thickness: 800 feet
Pump type: Electric Submersible	Depth to pump suction: 370 feet
Final pumping rate: 0.1 gpm	Type of test: [✓] constant rate [ ] step drawdown



Calculations:

$$T = \frac{114.6\,QW}{S} = \frac{114.6 \times 0.1 \times 0.1}{4} = 0.29 \quad \text{gpd/ft.}$$

$$S = \frac{Tt}{2693(r^2)\Theta} = \frac{x}{2693(1080)^2 \times 10} = 9.1 \times 10^{-8}$$

Where:

W and Θ are constant values for a given match point.

$$\varrho = \frac{r}{h}\left[\frac{k_v}{k_h}\right]^{1/2}$$

h = thickness of aquifer.

Q = Average pumping rate (gpm)
S = Drawdown (feet)
r = Radius from pumped well (feet)
t = Time (minutes)
S = Storage coefficient
T = Transmissivity (gpd/ft.)

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