Dr Tanner

EVALUATION OF MAGNETIC SUSCEPTIBILITY LOGGER

BY

Pierre Lapointe

B. Chomyn

GEOMAGNETIC SERVICE OF CANADA

INTERNAL REPORT 83-1

DIVISION OF SEISMOLOGY AND GEOMAGNETISM

EARTH PHYSICS BRANCH

DEPARTMENT OF ENERGY, MINES AND RESOURCES

APRIL 1983

Introduction

Magnetic properties are used in E.M.R./E.P.B. within different programs to define geological phenomena that have affected or are characteristic of different rock units. Magnetic properties are used in programs such as paleomagnetism, airborne and ground geophysics and the Nuclear Fuel Waste Management Program (NFWMP), to name a few. Over the last five years with the NFWMP, magnetic properties have revealed themselves as a powerful tool to characterize rock bodies and also characterize the state of that rock. In granite the most meaningful property has been magnetic susceptibility [Lapointe et al., 1983, Chomyn and Lapointe, 1983].

Background

What is magnetic susceptibility? What is the geological knowledge gained from it?

In simple terms magnetic susceptibility is the ease of a rock to be magnetized temporarily when subjected to a given magnetic field. This temporary magnetization reacts differently depending on the chemical composition of the oxides and their grain size. Measurements also may detect a preferred orientation of these oxides which is then a measure of the anisotropy of susceptibility. Since the oxides are the major magnetic mineral carriers, any modification of these oxides has a direct impact on their magnetic properties, and as oxidation is a widespread phenomenon highly sensitive to changing geological environment, the study of magnetic properties is a means by which one can untangle the rock history [Haggerty 1976]. Magnetic susceptibility is a direct measure of the oxides within a given rock, thus the interpretation of magnetic susceptibilities can then reveal a good part of the rock's geological history. Such features as fractures, alterations haloes around these fractures, level and extent of alterations, and degree of homogeneity of a rock body are features which can be quantitatively expressed using magnetic properties.

Magnetic susceptibility has been used in mining exploration for iron [Sharpe, 1953] and also for uranium [Hafen et al., 1976]. Anisotropy of susceptibility has been used in coal, tar sand, structural analysis of fold belt and as paleocurrent indicator in sedimentological studies. It has also led to fine magnetic interpretation over magnetic anomalies [Henkel, 1977] and has also been used in differentiation of metamorphic grade in Precambrian Shield [Krutikhovskaya et al., 1979]. The geological usefulness of magnetic properties is well established and documented. An extensive list of the pertinent references is available.

Within the magnetic properties tasks of the NFWMP it has been shown that magnetic susceptibility measurements on cores from deep boreholes is one of the most sensitive techniques for the characterization of the rock and rock state [Chomyn and Lapointe, 1983 see Fig. 1 attached]. It is important to realize that the measurements are done on cores at different length intervals. They are not done continuously in the boreholes. Over the last four years it has become clear that a magnetic susceptibiity logger would be a welcome addition to the set of logs already available within NFWMP. The purpose of this proposal is to seek ways to obtain or have access to a magnetic susceptibility logger [MSL]. The main usage of the MSL would be in the NFWMP, although it is foreseen that it would be of high interest in mineral explorative industry.

Scenarios

There are several scenarios that one can propose to obtain or to have access to an MSL. First there are commercial ones available, like the Simplec from USA, there is also a Finnish TH-3C instrument and also a Czechoslovakian one. For the latter, technical specifications of the instrument are apparently unavailable. Both the Simplec and the Finnish instruments are designed for iron exploration and they are not sensitive enough for work in the NFWMP, especially when dealing with low magnetized body. The USGS has modified Simplec probe to increase sensitivity to have a better control on the thermal effect when going down the boreholes. [Daniels, 1982 personal communications]. They have succeeded in doing this, but at a high cost in development time.

A second possible scenario is that E.P.B. (with possible collaboration with G.S.C.) through its Instrumentation Section will design and build a unit. The Instrumentation Section certainly has the expertise to do this together with the software and acquisition system. The Instrumentation Section is lacking expertise in the borehole aspect (winch, etc.) and would need to work in collaboration with G.S.C.

A third scenario is to go outside, to get a firm to design/build so that we would be in a position to buy or rent such an instrument.

A proposal was recently sent to me by SYGEC from Montreal in this regard (attach). Similarly another company NUMAC from Toronto has applied for an O.D.M. development grant to build a borehole tool consisting of a 3 component magnetometer using ring core technology, and plans to include a susceptibility logger (attach). This company has signed an agreement with the Finnish company which produces the MSL so that this consortium will produce the second generation of MSL with a sensitivity of +5 x 10 SI. This is the sensitivity needed in the NFWMP program. The Swedish Geological Survey is presently a user of MSL for their NFWMP. Their data will be available to us in early summer so that we can judge the reliability and quality of data.

From the information obtained during my recent trip to Sweden and from the new development presently going on, I suggest that the rock magnetic properties proposal for obtaining or having access to an MSL be delayed until further development on the Ontario Department of Mines development grant to NUMAC is known (end of March) and that the user report of the Finnish MSL is available to me from Sweden(+,-May). If the NUMAC grant is accepted, they propose to have the instrument ready in 6 months time. I am in contact with NUMAC and will be kept informed of the situation.

I conclude that it is preferable to await these developments before proposing concrete action either to AECL or for ourselves and the G.S.C.

REFERENCES

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Haggerty, S.E. 1976. Oxidation of Opaque Mineral Oxides in Basalts. In Oxides Minerals, Vol. 3, Chap. 4, Min. Soc. of Am., Virginia.

Sharpe, J.A., 1953. The magnetic susceptibility of rocks its determination and usefulness. Proc. Geophysical Soc. of Tulsa Memorial Vol., p. 23-43.

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Krutikhovskaya, Z.A., I.M. Silina, M.M. Bondareva and S.M. Podolyanko, 1979. Relation of magnetic properties of the rocks of the Ukrainian Shield to their composition and metamorphism, C.J.E.S., Vol. 16, p. 984-991.

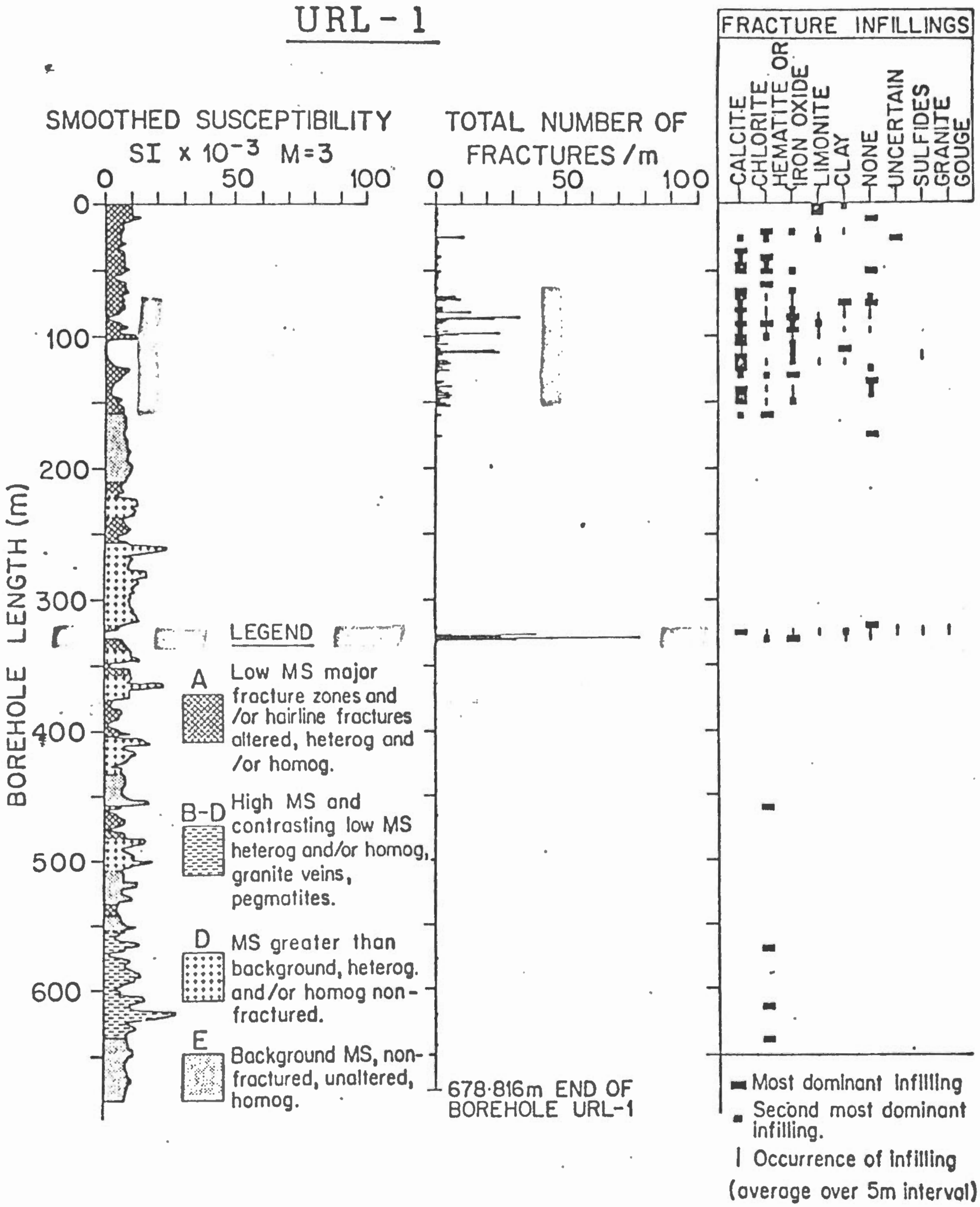

Figure 4. Comparison between lithological, fracture and magnetic susceptibility logs for URL-1. Note the correlation between fractured rock and regions of magnetic lows.

Fig 1a →

Fig 1d

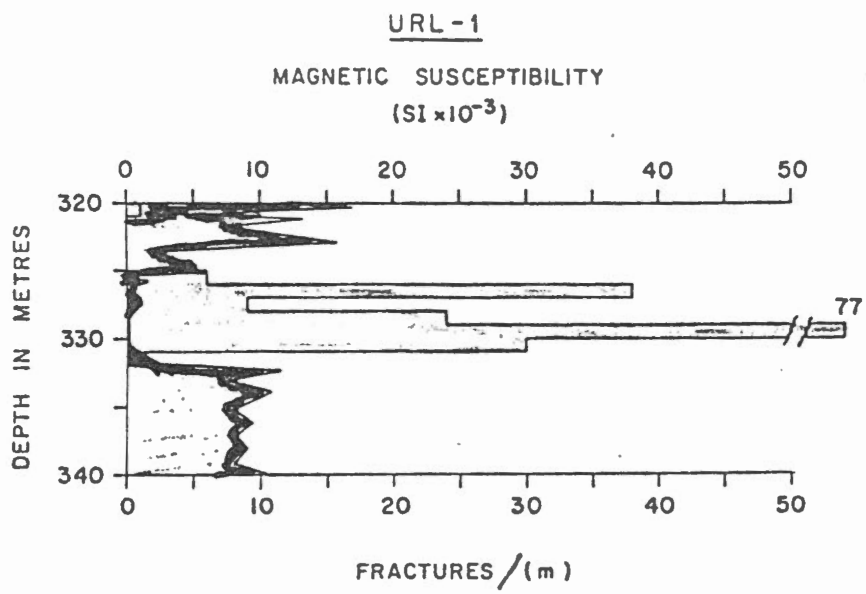

Fig. 8. Raw data plot of susceptibility of a second fracture zone at greater depth in URL-1. Measurements taken at 10 cm intervals.

SYGEQ

Le 27 octobre 1982

M. P.Lapointe
Division du géomagnétisme
Direction de la Physique du Globe
Energie,Mines et Ressources Canada
1 Place de l'Observatoire
Ottawa Canada
K1A OY3

Cher Pierre,

Cette lettre fait suite à notre rencontre de vendredi le 15 octobre 1982 concernant le développement d'une sonde de susceptibilité magnétique et de l'appareillage requis pour effectuer des mesures en continu dans les trous de forage. Un projet de proposition a été élaboré du moins en ce qui concerne les idées majeures tenant compte de cette rencontre, de nos conversations téléphoniques, de notre expérience en mesures dans les trous de forage et des rapports techniques disponibles. Le projet çi-inclus demeure sujet à modifications à mesure que se préciseront les détails de la proposition.

J'espère que ce projet correspond au moins dans ses grandes lignes, aux exigences de la Division du géomagnétisme.

Bien à toi,

Jean Roy

Jean Roy

Incl.

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PROJET DE PROPOSITION CONCERNANT LE DEVELOPPEMENT D'UNE SONDE DE SUSCEPTIBILITE MAGNETIQUE ET DE L'APPAREILLAGE DE MESURES EN FORAGES

Cette description comporte cinq sections à savoir: nature du projet, équipement requis par DPG, description de la sonde, étapes du projet de développement,échéancier et financement.

I Nature du projet.

Le projet consiste à developper et fournir à la Direction de la Physique du Globe (DPG) une sonde de susceptibilité magnétique dont les performances sont supérieures aux sondes actuellement sur le marché de même que le système de mesures en continu pour forage. En plus du développement de la sonde elle-même Sygeq est intéressé à la fabrication de telles sondes sur une base commerciale et à offrir le service de diagraphie de susceptibilité en complément aux autres diagraphies déjà offertes.

II Equipement requis par DPG

L'équipement suivant sera fourni à la DPG à la conclusion du projet:

- sonde susceptibilité magnétique
- treuil à vitesse de cable régulée et à interface numérique
- 2000 mètres de cable de diagraphie
- modules de surface:
  - contrôle sonde
  - interface treuil
  - conditionnement des données
  - communication avec systême acquisition

D'autrepart l'équipement suivant est possiblement déjà disponible à la DPG:

- systême acquisition et contrôle des données (ex. Osborne)
- génératrice électrique

III Description de la sonde

... 2

La sonde à développer peut être décrite par les caractéristiques suivantes:

- Paramètres de mesures: susceptibilité magnétique et conductibilité électrique
- Résolution requise sur l'échelle la plus sensible: K: 10^{-6}
- Gamme dynamique: K: 10^{-6} à 1 CGS
- Facteurs à optimiser: Dérive minimale des zéros et du calage de phase
- Pression maximum: 3000 psi (2000 m)
- Ajustement à partir de la surface
- Gamme de température de 0 à 30 °C
- Diamètre extérieur maximum 35 mm.

Pour les raisons qui suivent nous proposons une sonde à deux bobines plutôt qu'à une seule: insensibilité relative au diamètre du forage, faible dérive thermique, rayon de mesure proportionnel à l'écartement des bobines (à l'intérieur d'une gamme limitée), sensibilité en K. Cependant les facteurs suivants peuvent être sacrifiés: simplicité de la diagraphie résultante et, dans les cas complexes, résolution spatiale.

Le mode de calibration reste à définir; parmi les configurations possibles on peut mentionner: - bloc de calibration à matériel perméable - structure externe à bobines auxiliaires - bobine de calibration interne.

La majeure partie du développement sera consacrée à la sonde elle-même.

IV Etapes du projet de développement.

Plusieurs des étapes énumérées çi-après pourront être développées simultanément. Une illustration du cheminement optimum sera produite lorsque les détails du projet auront été définis.

Les principales étapes sont les suivantes:

- Définition et optimalisation des constantes de la sonde: Configuration exacte des bobines, dimensions géométriques, fréquence d'opération, détermination des sensibilités des paramètres géométriques par rapport à: sensibilité en K et σ dérives des zéros.

... 3

- Sélection et essai des matériaux de base: capteur, sonde etc.
- Conception, construction et mise au point des circuits de la sonde (sections analogiques et numériques)
- Conception, construction et mise au point de la sonde physique
- Conception, construction et mise au point des modules de surface:
  - contrôle sonde
  - interface treuil
  - conditionnement des données
  - communication système acquisition
- Modifications du treuil : vitesse de cable constante, mesure numérique de la profondeur, système de sécurité et interface
- Conception, construction et mise au point du système de poulie
- Montage du cable et pied de cable; vérifications treuil, cable, mesure profondeur, sécurité, interface
- Essai sonde et système en laboratoire: - hydrostatique -dérives en fonction de pression, température, traction, accélération - calibration initiale - mesure des rayons effectifs de mesures K
- Essai sur le terrain: - forage à susceptibilité mesurée sur carotte: St-Jérome si la DPG est prête à mesurer la carotte ou dans le cas contraire, Chalk River - forage à 2000 m à comptabiliser de façon externe.

V Echéancier et financement

Le projet n'étant pas encore arrêté, une évaluation détaillée des coûts est prématurée. L'ordre de grandeur de ces derniers peut être estimé entre 2 et 3×10^5 \$ en supposant que les détails techniques ne soient pas modifiés de façon significative. En évaluant le travail requis à environ 24 hommes-mois répartis sur 18 mois et en adoptant le mode de paiements échelonné, on peut prévoir une tentative de scénario tel que décrit çi-après:

MOIS	ECHEANCE	PAIEMENT PARTIEL
0	Accord final sur le projet	
2	Plan du senseur	1
5	Réception cable et treuil	2
7	Programmes-Schemas-Plan du système	3
10	Construction sonde terminée	4
14	Construction système terminée	5
16	Fin des essais de laboratoire	6
17	Fin des essais de terrain	7
18	Livraison de l'équipement	8

Dans la préparation d'un tel scénario on doit tenir compte des délais de livraison sur le cable et le treuil d'une part et sur

certaines composantes instrumentales qui ne pourront être commandées qu'une fois que les plans et schémas auront été faits. Il existe parfois des délais de livraison de l'ordre de six mois pour certaines composantes électroniques.
Ceci termine la description du projet; ce dernier demeure sujet à modifications suite aux discussions le concernant.

Soumis de Montréal, le 29 octobre 1982

Jean Roy

Jean Roy, Ingénieur

Numec Limited

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(416) 669-2279
(416) 669-2579

Mailing Address
P.O. Box 862
Concord Ontario
Canada L4K 1C8

Telex 06-984777

APPLICATION FOR EXPLORATION TECHNOLOGY

DEVELOPMENT FUND

BOREHOLE MAGNETIC PROPERTIES LOGGER

"MAGLOG"

Submitted By:

NUMEC LIMITED-Contractor

W.R.Thuma B.Sc. P.Eng.

83-01-14

Ministry of Natural Resources Ontario

Application for an Exploration Technology Development Fund Grant

Project Number

For Use By Applicant	
☒ New Application	☐ Renewal
If Renewal: Grant No.	
Date of this application 83-01-14	

Deadline for submissions is January 15, (funding period April 1st to March 31st).
Six (6) Copies of all documents must be submitted.
Please consult the current E.T.D.F. Brochure and instructions on reverse side before completing this form.

Principal Applicant:	Company (Name and Address):
NUMEC LIMITED	96 Bowes Road #11 P.O.Box 862 Concord, Ontario L4K 1C8
Applicant's Telephone No: (416)669-2579 Telex 06-964777	Location of Program: Ontario

Short Title of Project:
Development of a Borehole Magnetic Properties Logging System

Synopsis of Project: The project will be a joint effort between Numec and two subcontractors to develop and test a microprocessor controlled high sensitivity logging system which will continuously measure three orthogonal vectors of the Earth's field, the magnetic susceptibility and conductivity.

Financial Summary (Fiscal Year - April 1 to March 31)			Starting Date: 83-04-01	Estimated Completion Date: 83-12-31
	Total Cost of Project	Fiscal Period	No. of Months	Renewal Applicants only
Estimate For This Year	$ 91,467	19 83 -19 84	9-10 months	Most recent ETDF Grant: (OGS share) $
Estimate For 2nd Year	$	19 -19		
Estimate for 3rd Year	$	19 -19		OGS Funds Awarded To Date: $
Total	$ 91,467	19 -19	9-10 months	

Funding: (attach details if space provided is insufficient)

NOTE: A separate detailed budget is required for the "current year's request"

Have you applied to any other company or funding agency for support of all or portion of this project?

(If yes please detail) ☐ Yes ☒ No

(Type and Sign) It is understood that the general conditions governing the Province of Ontario Exploration Technology Development Fund as outlined in the current E.T.D.F. Brochure are hereby accepted and agreed to.

Authorized Executive Officer	Authorized Executive Officer
Thuma B.Sc. P.Eng. VP	
Name and Title — please type)	Signature:

BUDGET REQUEST FOR YEAR 1983

Section 1:

Personnel Services

Direct Labour	Hours	Salary*	Benefits*	TOTAL*	Total Est. Cost
-Supervision	480	$18.26	$ 3.65	$21.91	$ 10,516.80
-Engineering	490	$16.83	$ 3.37	$20.20	$ 9,898.00
-Technicians	960	$11.20	$ 2.24	$13.44	$ 12,904.40
-Draftsmen	60	$ 8.35	$ 1.67	$10.02	$ 601.20
				Subtotal........	$ 33,918.40

Direct Material

1. Test Equipment	$ none
2. Supplies and Materials Consumed. Including electronic components, PCB's, mechanical parts materials, drafting supplies, etc.	$ 10,765.00
3. Support Equipment (Capital). Including Digital Data Acquisition Unit, Analog Chart Recorder, Magnetic Susceptibility/Conductivity Meter, Transit Case and Winch (lease).	$ 26,760.00
Subtotal........	$ 37,525.00

Other Costs

-Travel, Field Testing	$ 2,802.00
, Consultants (Geoinstruments)	$ 2,400.00
-Patent Costs	none
-Testing Services. Including Hydrostatic Tests and Helmholtz Tests.	$ 800.00
	$ 6,002.00

*Expressed in $/hr.

BUDGET REQUEST FOR YEAR 1983-Continued

Sub-Contractors:

Name and Address	Type of Work	Contract	Estimated Costs
IFG Company 18 Bram Court #5 Brampton, Ontario L6W 3R6	Electronic Design & Software Development.	Hourly rate	$ 11,392.00
Geoinstruments Ky Punapaadentie 6 SF-00930 Helsinki Finland	Electronic Design	Daily rate + expenses	$ 2,630.00
		Subtotal.......	$ 14,022.00
		TOTAL YEARLY PROJECT COST......	$ 91,467.00

Section 2:

Total Project Cost-Estimated Spending Pattern

First Year 1983/1984 (a) $49,935 (b) $26,741 (c) $12,365 (d) $ 2,427

Second Year--not projected.

Note: Refer to Table #1 for details of Calanderization of Expenses.

TABLE #1 DETAILED CALENDARIZATION OF EXPENSES

Cost Centre		Month 1	2	3	4	5	6	7	8	9	10
Labor-Supervision	$	1096	1753	1753	1315	1096	876	438	876		1315
-Mech. Design	$	808	2424	2424	2222	1010	606				404
-Elec. Design	$	1534	1753	2191	1972	1095	438	219	876	876	438
-Elec. Design	$	876	876	438		219	219				
-Elec. Assembly	$		1210	1613	1613	1613	1344	941	538	269	
-Mech. Fabri.	$		538	538	1075	941	672				
-Documentation	$	20	20	120	20	20	120	20	20	120	120
Subtotal..............	$	4334	8574	9077	8217	5994	4275	1618	2310	1265	2277
Material	$	750	2050	3100	3500	1140	75				150
Capital Expenditures	$		9850	9800	300	2050	1190	1190	1190	1190	
Misc.-Field Test	$									2802	
-Travel/R&B	$		2400								
-Outside Testing	$							800			
TOTAL................	$	5084	22874	21977	12017	9184	5540	3608	3500	5257	2427

SUMMARY: Labor $47941(5.5% outside Ontario)

Time 2630 Man-Hours

Matl $37225(26% outside Ontario)

Other $ 6002

ii. Abstract of Proposed Development

Numcc Limited proposes to develop, manufacture and test a high sensitivity Magnetic Properties Logging System("MAGLOG") for use small diameter drill holes. The System will allow continuous logging to depths of at lease 1000m of a). the three orthogonal components of the Earth's total field, F, to accuracies of ±0.1nT, b). magnetic susceptibility to lower limits of $5x10^{-5}$ SI units and c). conductivity to ±0.1 mho/m. In addition, the microprocessor will calculate the total field to an accuracy of ±0.3nT.

The MAGLOG will operate in high magnetic gradients which have previously created design problems particularly in those attempts to use proton precession techniques. The entire System will be modular in configuration and designed for use in the harsh environments typically experienced in mineral exploration. Controls and functions will be minimized and simple, with many under the control of the microprocessor. All data will be stored digitally for high speed processing on main frame computer or field micros. The output will be compatable with commonly available hardware and software. Real time varification will be made available on a small multichannel chart recorder integrated into the System.

Numec intends to conduct the development in close cooperation with two subcontractors, each with special experience relative to the project. The first, IFG Company(Ontario) will be responsible for much of the electronic design and software development. This company has extensive experience in the field of magnetics and microprocessor technology. The second company, Geoinstruments Ky, will contribute expertise in magnetic susceptibility measurements.

Numec will provide supervision, direction, technical support, facilities, mechanical and electronic design, fabrication, parts procurement, assembly, advanced marketing and administration of the project.

The "MAGLOG" project is expected to require 9-10 months to complete and should commence on 1 April 1983. Onec the basic system has been field proven, it is anticipated that other areas of development will become evident. These may be appropriate for additional funding requests for the next fiscal year.

Table of Contents

PROJECT PROPOSAL

A. INTRODUCTION

The measurement fo rock physical properties in boreholes is an increasingly important aspect of mineral exploration. Data obtained from logs is directly input into formulae and programs to refine and improve conceptual models. Parameters commonly measured include density, resistivity, acoustic velocity, IP effect, EM conductivity and spectral gamma radiation. However, in the 50 years or more of the development of logging techniques, one of the more important properties has remained out of the reach of instrument designers. Several attempts have been made to measure the earth's magnetic field but for a variety of reasons these have not resulted in commercially available systems.

To the author's knowledge, two systems have been field tested. The first is a fluxgate designed by a Swedish company over a decade ago. Three systems were produced and one is still in use after extensive modification in South Africa. The research staff at Lawrence Livermore Labs tried shallow logging using proton precession techniques in the mid-70's but nothing was heard of the project after the initial tests. Several groups have experimented with measuring magnetic susceptibility in boreholes and one, Anaconda, has successfully applied it to exploration for uranium in the U.S. Little has been published on the above.

Numec Limited, in cooperation with IFG Company and Geoinstruments Ky propose to develop, test and make commercially available a microprocessor controlled system which will measure the Earth's magnetic field in three orthogonal directions, calculate the total field, and measure the magnetic susceptibility and conductivity in small diameter drill holes. The system hereinafter called the "MAGLOG" for Borehole Magnetic Properties Logger will be designed for use in both mineral and petroleum logging. It's full description follows under Section C.

B. BACKGROUND EXPERIENCE

Numec Limited has direct experience in the design and use of logging systems and components. Since 1975, it has served the equipment manufacturers by providing the CLW Series Geophysical Winches. Units are in use worldwide in systems provided by Scintrex, McPhar, Geonics and Geoex. In addition, Numec has designed special probes adn header assemblies for use to depths of 1000m. On the electronic side, it manufactures a base station magnetometer, airborne multichannel chart recorder and a small EM system . It operates a precision machine shop which serves it's own needs and those of other scientific instrument manufacturers including

Urtec, EDA Instruments, Sciex, Aptec Engineering, Moniteq, McPhar and de Havilland Aircraft. Technically, the author is a mining geophysicist and registered professional engineer(Ontario) with broad field experience including seismic, IP and EM logging. Another principal in Numec has designed a variety of portable geophysical instruments over the past 15 years including those products currently manufactured by the company.

IFG Company is a local Ontario company which designs and manufacturers geophysical instrumentation including the DATA-1 Airborne Digital Data Acquisition System and a small base station magnetometer. Their principal designer(and owner) has in the past designed the McPhar RD-600 Borehole Logging System as well as complete airborne radiometric systems. Most recently, IFG has been developing an airborne three component fluxgate magnetometer, the basic concept of which will form the electronics portion of the MAGLOG.

Geoinstruments Ky is a Finnish company operated by a geophysicist with wide experience in the use and development of airborne, ground and borehole geophysical instruments. The company currently manufacturers several instruments including a susceptibility and conductivity meter which will be adapted for use in the MAGLOG System. Geoinstruments has the backing of the Exploration department of Rautarukki Oy, one of the two largest mining companies in Finland.

Many of the products mentioned above are described in detail in the brochures to be found in the Appendix, Section E.

C. PROPOSAL

C.1. General Description, Applications and Benefits

Numec Limited proposes the development of a complete Borehole Magnetic Properties Logger(MAGLOG) which will be capable of continuously measuring and recording:

- Three Components of the magnetic field, F;
- Vector sum of above to produce F;
- Magnetic Susceptibility; and
- Conductivity.

The MAGLOG will have many direct and indirect applications including:

- Lithologic identification;
- Exploration for economic mineralization associated with specific ferromagnetic minerals or specific horizons which exhibit a characteristic signiture;
- Aid in the interpretation of aeromagnetic and ground magnetic surveys;
- Age dating by the analysis of field reversals;

Research into magnetic interpretation, modeling and the variation of magnetic properties; and

Mine grade control.

From the user point of view, the system would benefit all sectors of the mineral industry of Ontario including exploration companies, the Geological Survey, geophysical survey contractors and universities. For the Province, it would contribute to the manufacturing sector and increase export trade.

The market for MAGLOG would be worldwide in scope. It would be promoted through Numec's network of 14 international representatives, most of whom are directly connected with the mining industry. In addition to this industry, Numec would investigate the potential of sales to the petroleum and geothermal industry during the course of the project. In total, no less than 5 systems could be sold in the first 6 months following the completion of the development.

In general terms, the MAGLOG System would consist of 4 major components, the portable electronic console, data recording units, winch/cable and probe assembly. A single transit case would contain the fluxgate/susceptibility/conductivity console, both analog and digital recorders, charger and power pack. The Winch with cable will also house a recorder servo control and digital fiducial counter for depth encoding. The probe will be segmented for carrying convenience and future expansion. Refer to Figure 1 for system layout.

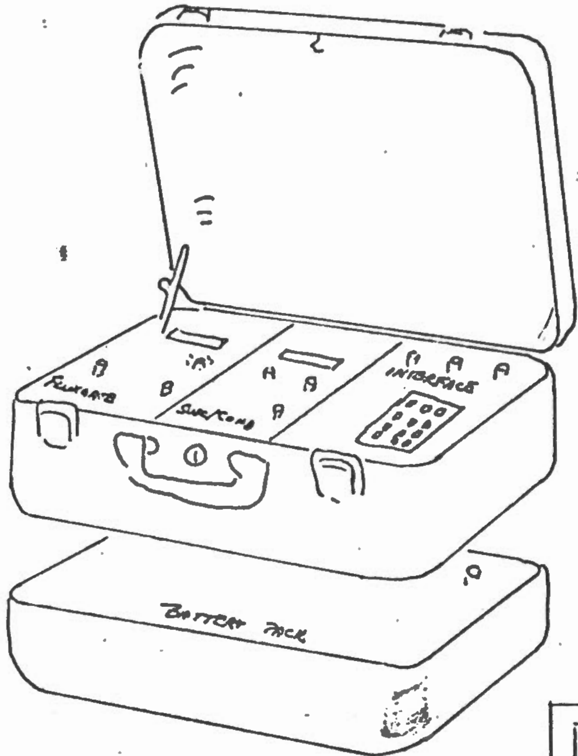
C.2. Specifications

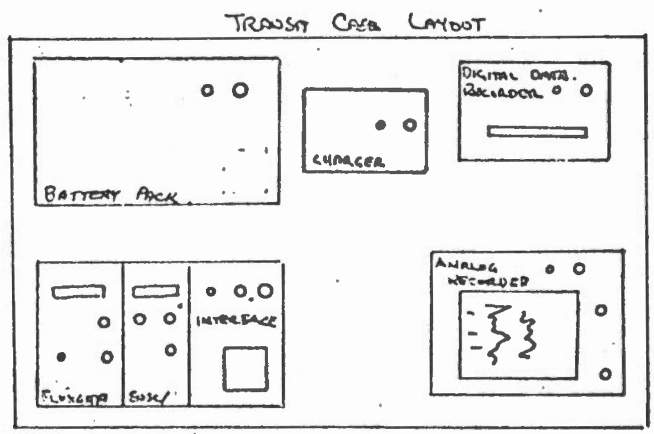
Tentatively the MAGLOG will have the following technical specifications and capabilities:

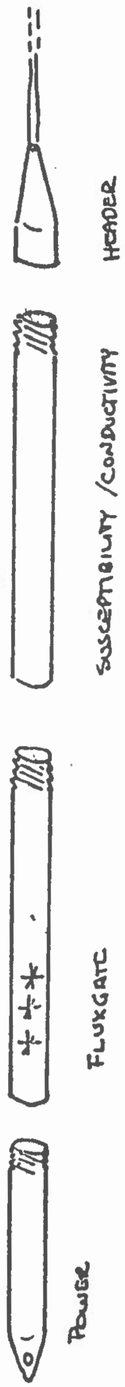
Measured Parameters [Accuracy and Range]	XYZ Orthogonal Components of F(referenced to the borehole axis) ±0.1nT(gamma) over ±100,000nT. Magnetic Susceptibility at $\pm 5\times10^{-5}$ SI from 0 to $\pm 200{,}000\times10^{-5}$ SI. Conductivity ±0.1 mho/m from 0.1 to 1×10^{3} mho/m.
Cycling Time	0.5 seconds or less.
Depth Capacity	Design minimum 1000m, potential to 6000m.
Temperature Range	Operational 0-70°c(probe) and -20°C to +55°C(surface electronics). Storage -40°C to +55°c.
Analog Recorder	Multichannel slaved to depth and reversable.

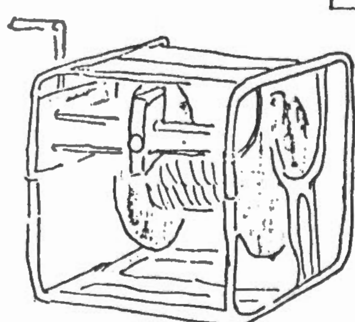
Figure #1

MAGLOG Component Configuration









CLW-2M WITH SERVO/INTERVALOMETER
AND 500m CABLE

NUMEC

DATE	DRAWN BY	CHECKED BY	ASSEMBLY
83-01-13	WRT		

MATERIAL	SCALE
	NTS
FINISH	

PART NAME	MODEL
MAGLOG	
	DWG. No

Digital Recorder	Cassette, solid state or disc.
Probe Dimensions	Minimum diameter 42mm, length 2.4m in sections of not more than 1.0m.
Power-Electronics	Rechargeable lead acid batteries.
-Winch	Manual or electric from 115 or 240V AC.

C.3. Individual Component Descriptions

SurfaceElectronic Console. This component would contain the fluxgate magnetometer, susceptibility/conductivity meter and interface modules. Power would be provided by a detachable rechargeable battery pack which would also serve to power the two recording devices. All modules would be sealed for use under conditions common to all drill sites. Controls will be simple and few, since most of the house keeping will be under microprocessor control. LCDs would indicate the total field and either the susceptibility or conductivity which would be switch selectable. The interface would control input signals, power distribution and output to the recording devices. It would also have a keypad for entering header information and for operator/software intercommunication.

Recording Devices. Primary data recording will be in digital form to allow re-cording all information over a full dynamic range. Several options are to be considered in the development including cassettes, solid state memory and floppy discs, the latter being the present choice. Design will permit the later selec-tion of a variety of digital recorder to offer the end user a choice which best suits his application and current data handling capabilities. No dumping device is contained in the proposal although compatability with popular hardware/soft-ware such as the HP-85 will be designed in initially.

The Analog Recorder will be a multichannel DC operated unit with a minimum of 2 channels plus fiducial. It will be reversable and slaved to the depth counter on the winch.

Winch/Cable. The winch will be a CLW-2M Motorized logging winch carrying 500m of 4 conductor(dual twisted pairs) data line cable. The winch servo will control the analog recorder speed and the intervalometer will produce digital signals for encoding the depth on both recording devices.

Probe. The probe assembly will be comprised of a header assembly, fluxgate sen-sors, susceptibility and conductivity sensors, signal conditioners and preamps.

All signals will be digitized for relay to the surface. The design will pay particular attention to reliable operation at elevated temperatures and depths expected to be encountered in petroleum logging.

Fluxgate Magnetometer Module. The fluxgate will use ring core sensors similar to those used in the current IFG airborne unit. They will be oriented in line over a probe distance of about 20cm. The preamp in the probe will be rated for high stability under relatively high temperatures. The surface module would contain a CMOS microprocessor.

Susceptibility/Conductivity Module. Susceptibility will be measured using a detector coil in the probe as part of a resonant bridge circuit. Unbalance of the bridge is directly proportional to magnetic susceptibility. Conductivity will be measured inductively using a frequency fo 1.4kHz. At this frequency, the best data will be obtained from reasonable conductors. At this point of the project it is assumed that the conductivity will interfer with the other measurements and it is expected that it will be logged on the opposite trip of the other two.

C.4. Work Plan

The project will be a joint effort involving Numec as the prime contractor and administrator, and IFG and Geoinstruments as subcontractors to provide specific expertise operating through Numec.

The MAGLOG Project is expected to take approximately 9 months to complete and will require the following individuals:

Name	Title	Task
W.R.Thuma B.Sc. P.Eng.	Geophysicist	Supervision, Technical Reference.
George Gee	Electromechanical Designer	Design, Production and Testing.
Detlof Blohm	Electronics Engineer	Electronic Design, software development, interfacing and testing.
Mikko Hamalainen B.Sc.	Geophysicist/Electronic design	Electronic Design and interfacing.
D. Kelly Maidens C.T.	Electronics Technician	Assembly and Testing.
David Tambling	Machinist	Mechanical design, fabrication and assembly.
Bonnie Robb	Typist	Report typing and Documentation.

All aspects of the design cycle are scheduled in the Work Plan, Table #2. Electronic design will take place over a period of 4½ months with mechanical design requiring 5+ months. Software programming will encompass the development of calculation algorithms, noise supression, parity checks, data formatting, various house keeping functions and test functions. Testing of both the hardware and software will occupy 4½ months of the project.

The project requires the purchase of many discrete electronic and mechanical parts which will be procured on a scheduled "as required" basis. Major capital purchases of the TH-3c Susceptibility/Conductivity Meter, analog chart recorder and digital data acquisition unit will take place in concert with the development of the other primary components.

C.5. Subcontractors Responsibilities.

IFG will be responsible for the redesign of their existing prototype airborne fluxgate magnetometer for integration into a borehole configuration. All circuits will be converted to low voltage operation and the sensors with preamps, A/D convertors, crystal oscillator and serialization circuitry will be designed to fit into the probe. Interfacing with the Geoinstruments instrument, software development and integration of the system with the recording units will be primary functions supervised by IFG.

Geoinstruments will provide the prototype susceptibility/resistivity meter for integration into the MAGLOG System. The designer of the TH-3c, Mikko Hamalainen, will accompany the instrument to Toronto and will spend 10 days with the contractor to effectively transfer the expertise necessary for Numec and IFG to proceed with the project.

C.6. Test Plans.

During the early stage of development, a comprehensive series of tests will be defined to insure the performance of the individual somponents, subsystems and the final system meet with the design objectives. Tests will take into account the limitations of individual components as well as applications requirements. In general, the tests which will be documented in the monthly reports, will include:

Bench Testing

- Data Output and Integrity
- Software performance and debugging
- Orientation Errors

TABLE #2. WORK PLAN SCHEDULE

TASK	Month 1	2	3	4	5	6	7	8	9	10
Electronic Design	Fluxgate---	---	---	---						
		Susc/Cond---	---	---						
			Interface---	---						
			Software---	---	---					
		Power---	---							
			Charger---	---						
				Servo---	---					
Mechanical Design		Fluxgate---	---	---						
		Susc/Cond---	---	---						
			Interface---	---						
		Power---	---							
			Charger---	---						
					Servo---	---				
				Winch-Case---	---	---				
Printed Ckt. Board Layout		---	---	---	---	---				
Assembly				---	---	---	---			
Mechanical Fabrication				---	---	---	---			
Bench Testing					---	---	---	---		
Field Testing								---	---	---
Major Purchases	**TH-3c									
			**Digital Data Acq. Unit							
			**Analog Recorder							
			**Cable		Winch Lease---	---	---	---	---	---
Reports*	M	M	Q	M	M	Q	M	M	Q	F

*M=monthly Q=quarterly F=final

Measurement Linearity

Environmental-

Temperature and Humidity Range

Immersion and Hydrostatic Pressure(Subject to the availability of chamber)

Thermal and Mechanical Shock

Battery Life

Field Test. Full operational field testing is the system is proposed at the Night Hawk Lake Geophysical Test Site located near Timmons. Surveys of the three drill holes planned for completion in 1983 will be conducted to the projected depth of 250m. Although the graphitic conductor to be intersected does not give rise to a surface anomaly, it may contain sufficient pyrrhotite to produce a detectable contrast. The rhyolite host rock should exhibit some inhomogeneity which at the sensitivities specified will produce minor anomalies. Multiple runs in each hole will be conducted to establish the repeatability of the system as well as it's drift characteristics. If core is available, the susceptibility and possibly the conductivity of the core will be logged for comparison with the logs. Data will be statistically analyzed, plotted and included in the final report.

In the event that the above test site is not drilled in 1983, the tests will be rescheduled to be done at the GSC Research hole located behind the GSC offices at 601 Booth Street in Ottawa. As another alternative, one of the several test holes drilled for the AECL Waste Repository program may be used.

C.7. Reporting Schedule

Monthly expenditure reports and quarterly progress reports will be submitted on the first of the month during the course of the project. The final report will be submitted within two months after the completion of the field test phase.

D. Future System Enhancements

Although not part of the 1983/1984 MAGLOG Proposal, it is considered essential to keep in mind the several aspects of the development which could enhance the use of the system. These may be considered for the followup proposal and include:

- Addition of an orienting or reference device to relate true north and the gravitational vector to the measured field components;
- Investigation of the effects of variable hole diameter on the susceptibility and conductivity measurements, and the development of practical correction routines using caliper log data;
- Addition of thermal sensing in the probe;
- Extending the depth capability to 6000m for application in softrock and deep

geothermal logging;

Development of interpretaion and data analysis software;

Applications and market analysis; and

Electronic and mechanical packaging optimization and production cost reduction.

E. Resumes

Name: W.R.Thuma B.Sc. P.Eng(Ont)   Employer: Numec Ltd.

Birth Date: 43-02-10   Title: VP

Education: B.Sc.(1965) Geophysical Engineering, Michigan Technological Univ.

Post Grdauate Studies, Geophysics, 1965-1967, M.T.U.

Experience: Texaco Inc. 1964 Seismic Survey Tech.

Calumet & Hecla Mining 1965-1967 Project Geophysicist

Anaconda Co. 1967-1968 Project Geophysicist

Anaconda American Brass 1968-1971 Assistant Chief Geophysicist

Chibougamau Mines 1972 Geophysicist

Scintrex 1973-1976 Instrument Sales Manager

Barringer Research 1977

EDA Instruments 1978-1982 Marketing Manager

Numec 1982 to Present VP

Publications: Advantages of Vertical Magnetic Gradiometer Data. Northern Miner, 15 April 1982.

The Use of Data Minus Gamma Radiometric Analysis in the Determination of Uranium in Ores and Concentrates, 1981(Unpublished)

Radon Detector is Increasing It's Important Role in Mine Safty, Northern Miner, 18 September 1980.

Name: George Gee   Employer: Numec Ltd.

Birth Date:41-11-29   Title: President

Education: Danforth Technical School(1960)

West Hill Colleagant (1961)

Devry Institute(1971)

Experience: Sangamo Electric 1961-1966 Mechanical Designer

Scintrex Ltd. 1966-1975 Mechanical Designer

Numec Ltd. 1975 to Present President

Name: Detlef Blohm | Employer: IFG Company
Birth Date: 42-12-08 | Title: President

Education: Rheininsche Engineering School(1965), Cologne, West Germany

Experience: Wandrer-Werke A.G. 1965-1967 Design and development of computerized banking systems.

Exploranium/Geometrics 1967-1975 Systems Engineering of airborne radiometric systems and design of radiometric instruments.

McPhar Geophysics 1975-1980 Chief Engineer, design of airborne geophysical data acquisition system and Borehole Logging System.

IFG Company 1980 to present Design of data acquisition system for high sensitivity magnetic gradiometer and three component fluxgate magnetometer

Name: Mikko Hamalainen M.S. | Employer: Geoinstruments Ky(Finland)
Title: President

Education: M.S. degree in Applied Geophysics(1975)

Experience: Geological Survey of Finland Two years

Geoinstruments Ky 1977 to present. Design of susceptibility meters including microprocessor based data logger.

Name: D.Kelly Maidens | Employer: Numec Ltd.
Birth Date: 53-12-17 | Title: Production Manager

Education: O.S.S.G.D.(1972)
Radio College of Canada(1974)

Experience:		
Scintrex Ltd	1974-1978	Airborne Geophysical Technician
Geoterrex	1978-1980	" " "
Numec Ltd.	1980 to present	Electronic Technician