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Porosity characteristics of mineralized and nonmineralized rocks from the Yellowknife mining district, Northwest Territories

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Abstract: Effective porosity measurements were performed on a suite of 17 samples from the Yellowknife mining district, Northwest Territories. The samples include massive flow, mafic volcanic flow, metagabbro, and talc-chlorite schist. The purpose of this study is to provide basic data to be used in the determination of petrophysical characteristics and electrical conductivity mechanisms of these rocks. The porosity data, when accompanied by other petrophysical measurements, can be used in the development of exploration strategies for aiding interpretation of downhole, ground, and electromagnetic surveys. This paper documents the results and describes the methods and processes used to obtain these porosity data.

Results indicate that bulk density (δ_B) and effective porosity (ϕ_E) values are in the ranges of 2.70 to 3.05 g/mL and 0.19 to 2.77%, respectively, for these samples. Massive flow, mafic volcanic flow, talc-chlorite schist, and metagabbro samples have porosity ranges of 0.19 to 0.39%, 0.27 to 2.60%, 0.45 to 0.75%, and 0.67 to 2.77% respectively.

Résumé : On a mesuré la porosité réelle de 17 échantillons provenant du district minier de Yellowknife (Territoires du Nord-Ouest). Les échantillons comprennent des coulées massives, des coulées volcaniques mafiques, du métagabbro et du schiste à talc et chlorite. Le but de cette étude est de fournir des données de base qui seront employées pour déterminer les caractéristiques pétrophysiques et les mécanismes de conductivité électrique de ces roches. Les données de porosité, lorsqu'elles sont accompagnées d'autres mesures pétrophysiques, peuvent servir à élaborer des stratégies d'exploration visant à faciliter l'interprétation des levés de forage, des levés terrestres et des levés électromagnétiques. L'article présente les résultats obtenus et décrit les méthodes et procédés appliqués pour recueillir ces données de porosité.

Les résultats indiquent que les valeurs de la densité apparente (δ_B) et de la porosité réelle (ϕ_E) de ces échantillons oscillent respectivement entre 2,70 et 3,05 g/mL et entre 0,19 et 2,77 %. Les intervalles de porosité dans les échantillons de coulées massives, de coulées volcaniques mafiques, de schiste à talc et chlorite et de métagabbro sont respectivement de 0,19 à 0,39 p. 100, de 0,27 à 2,60 p. 100, de 0,45 à 0,75 p. 100, et de 0,67 à 2,77 p. 100.

INTRODUCTION

Effective porosity measurements were performed on a suite of 17 samples from the Yellowknife mining district, Northwest Territories. The purpose of this study is to provide basic data to be used in the determination of petrophysical characteristics and electrical conductivity mechanisms of these rocks. The porosity data, when accompanied by other petrophysical measurements including electrical resistivity and bulk density, will be used in the development of exploration strategies for aiding interpretation of downhole, ground, and electromagnetic surveys. The samples include massive flow, mafic volcanic flow, metagabbro, and talc-chlorite schist. This paper describes the methods and processes used to obtain the porosity data and documents the results in as much detail as considered necessary for subsequent studies.

METHOD OF INVESTIGATION

Samples and sample preparation

The 17 samples used in this study were collected by Jonathan Mwenifumbo (GSC-Ottawa) from drillhole S2141 in the Yellowknife mining district, Northwest Territories. Each sample consists of a 4 cm diameter core section of up to approximately 20 cm in length. The samples were chosen on the basis of rock type (for accurate background rock characterization) and anomalous geophysical signatures. Information on sample depth and type is listed in Table 1.

For clarification purposes, a 'sample' herein is a section of core obtained for various analyses. A 'specimen' is a section of material cut from a sample to be analyzed. Usually more than one specimen is cut from each sample to isolate any heterogeneities present in each section of core. Rectangular and/or partial disc specimens are used for the determination of bulk density (δ_B) and one specimen is used for the determination of effective porosity (ϕ_E) whenever possible. Samples with a high sulphide content are not used for the porosity determination because of concern over their possible oxidation under moist conditions at elevated temperatures (100°C). In this study, 22 specimens were used for effective porosity measurements.

Bulk density and effective porosity measurements

The caliper method (American Petroleum Institute, 1960) has been used to determine the bulk density (δ_B) of samples by measuring the dimensions and weight of the rectangular and partial disc specimens. This measurement constitutes part of the porosity-determining procedure. In principle, effective porosity (ϕ_E) represents the pore volume of all interconnected pores. In this study, it is determined from the difference in weight between an oven-dried and water-saturated rock specimen. The American Petroleum Institute (1960) recommended practice for core-analysis procedures has generally been followed in these measurements. The procedures routinely used in our measurements are described in the literature (e.g. Katsube and Scromeda, 1991; Katsube et al., 1992; Scromeda and Katsube, 1994).

EXPERIMENTAL RESULTS

The results of the bulk density determinations and effective porosity measurements are listed in Table 2. The bulk density values are in the range of 2.70 to 3.05 g/mL and the effective porosity values are in the range of 0.19 to 2.77%. Two anomalously high effective porosity values were found, one for a mafic volcanic flow sample (MYI-2; ϕ_E = 2.60%) and another for a metagabbro sample (MYI-9; ϕ_E = 2.77%). In general, the massive flow samples seem to have lower effective porosity values than the mafic volcanic flow samples. The results of the effective porosity measurements are shown in

Table 1. Descriptions and depths of rock samples collected from drillhole S2141 (Yellowknife mining district, Northwest Territories).

Sample number	Depth (m)	Lithology	Comments on downhole log observations (J. Mwenifumbo, pers. comm., 2000)
MYI-1	12.8	Massive flow	>25 000 Ω·m
MYI-2	25.91	Mafic volcanic flow	deformed pillow selvages
MYI-3	39.62	Mafic volcanic flow	part of a shear zone
MYI-4	76.2	Massive flow	>10 000 Ω·m, small IP effect, Qtz-cal-py
MYI-5	84.73	Massive flow (dyke?)	>30 000 Ω·m, high density
MYI-6	99.97	Massive flow	susceptibility anomaly
MYI-7	106.68	Chlorite schist (metagabbro?)	~20 000 Ω·m, high gamma (thorium)
MYI-8	114.9	Massive flow	high susceptibility, Qtz-carb-chl shear
MYI-9	120.7	Meta gabbro	interesting gamma, low ρ
MYI-10	137.77	Mafic volcanic flow	High IP, susceptibility, magnetic
MYI-12	150.88	Metagabbro	>10 000 Ω·m, high gamma
MYI-13	169.77	Mafic volcanic flow	>20 000 Ω·m
MYI-14	188.98	Talc-chlorite schist	high density
MYI-15	199.95	Mafic volcanic flow	>10 000 Ω·m, chloritized
MYI-16	204.22	Talc-chlorite schist	
MYI-17	208.79	Mafic volcanic flow	High IP, Au, sheared sericite-chlorite schist
MYI-18	224.03	Mafic volcanic flow	High IP, ρ, sericitized silicified shear

Table 2. Results of bulk density and effective porosity measurements.

Sample	δ_B (g/mL)	W_W (g)	W_D (g)	S_{ir} (%)	ϕ_E (%)
MYI-1	2.93	5.9417	5.9374	55.8	0.21
MYI-2A	2.70	4.3376	4.2963	8.0	2.60
MYI-3A	2.94	2.9089	2.9031	24.1	0.59
MYI-3B	2.85	3.1310	3.1208	10.8	0.93
MYI-4B	2.92	3.0374	3.0336	50.0	0.37
MYI-5A	2.93	3.8664	3.8632	40.6	0.24
MYI-5B	2.96	4.4439	4.4410	44.8	0.19
MYI-6	2.84	4.8981	4.8945	55.6	0.21
MYI-7	2.89	4.5213	4.5143	44.3	0.45
MYI-8A	3.00	4.6042	4.6003	51.3	0.25
MYI-8B	3.05	2.9121	2.9084	37.8	0.39
MYI-9	2.78	2.8717	2.8434	9.9	2.77
MYI-10	2.86	5.6133	5.6035	52.0	0.50
MYI-12	2.96	4.4030	4.3931	60.6	0.67
MYI-13	3.05	3.8908	3.8829	59.5	0.62
MYI-14	2.93	6.4216	6.4053	31.3	0.75
MYI-15A	2.87	3.6403	3.6180	35.9	1.77
MYI-15D	2.85	2.9021	2.8887	35.8	1.32
MYI-16	2.87	11.9207	11.8993	32.7	0.52
MYI-17	2.93	5.1120	5.1046	31.1	0.43
MYI-18A	2.84	4.2339	4.2290	49.0	0.33
MYI-18B	2.81	4.3245	4.3204	51.2	0.27

W_w = wet weight; δ_B = bulk density
W_D = dry weight; ϕ_E = effective porosity
S_{ir} = irreducible water saturation

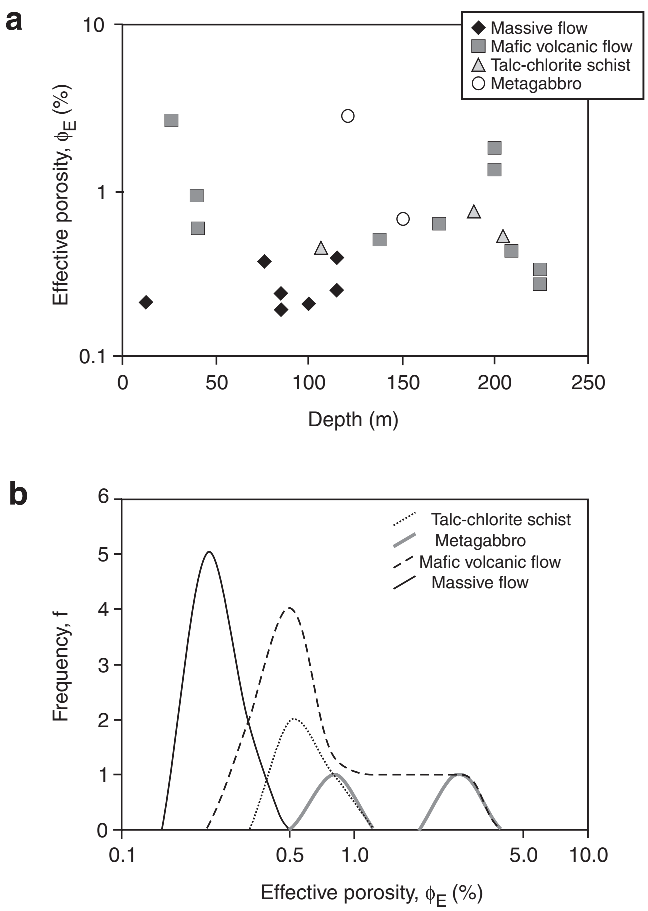

*Figure 1. Effective porosity (ϕ_E) for the mineralized and nonmineralized samples; ϕ_E displayed **a)** as a function of depth and **b)** as a histogram.*

Figures 1a and b. Figure 1a presents effective porosity versus depth for the different rock types. Figure 1b, a histogram, presents effective porosity distribution patterns for the different rock types.

DISCUSSIONS AND CONCLUSIONS

The bulk density and effective porosity values of these samples are in the ranges of 2.70 to 3.05 g/mL and 0.19 to 2.77%, respectively. The higher bulk density values are similar to those of basic rocks and the lower ones, to those of sedimentary rocks (Daly et al., 1966). The lower effective porosity values are typical of crystalline rocks (Katsube and Mareschal, 1993; Katsube and Scromeda, 1995). Three samples (MYI-2, MYI-9, and MYI-15) show anomalously high effective porotisy values that are similar to those of tight sedimentary rocks (Daly at al., 1966). For the most part, samples with higher porosities have lower bulk densities, as would be expected. However, two exceptions were found. Samples MYI-2A and MYI-9 both have higher porosities and higher bulk densities (2.60%, 2.70g/mL and 2.77%, 2.78 g/mL respectively) when compared to the others. Sample MYI-9, a metagabbro, has a pitted surface and contains carbonate residues that may have dissolved upon saturation of the porosity specimen. This could account for the higher effective porosity value of 2.77%. Sample MYI-2 is from a mafic volcanic flow, for which samples show generally high effective porosity values (Fig. 1b). In contrast to the mafic volcanic flow, which shows an effective porosity distribution of 0.27% to 2.60% (Table 2), with a mode of 0.50% (Fig. 1b), the massive flow shows an effective porosity distribution of 0.19% to 0.93% (Table 2), with a mode of 0.20% (Fig. 1b). Further studies are underway to determine the quantitative relationship between the mineralogy and the physical properties, such as electrical resistivity and scanning electron microscope analysis.

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