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FTIR MICROSCOPE ANALYSIS OF DIAMOND AND INDICATOR MINERALS AS A NEW TOOL IN PROSPECTING FOR DIAMOND DEPOSITS

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INTRODUCRION

During the course of prospecting for diamond deposits, FTIR analysis has, to date, only been applied to diamond, and generally this is used merely as a supplementary technique. FTIR analysis may, however, be efficiently utilised in the prospecting of diamond and of diamond indicator minerals as well and can therefore be viewed as an efficient prospecting tool. This technique can be performed as an express method and can be carried out in the field, which makes it competitive to field-mineralogical analysis.

For the analysis, the heavy fraction of mineral samples is studied under FTIR microscopy. This method allows for: (1) the identification of both diamond and diamond indicator minerals (*e.g.*, garnets of variable composition, clino- and orthopyroxenes, olivine, chrome spinel, zircon, apatite and other minerals) without any special sample preparation; (2) to identify, among indicator minerals, specific kimberlite (or lamproite) indicator minerals (KIM); and (3) to establish diamond and KIM 'fingerprints' for known or new primary diamond sources. In addition, routine morphological and optical characteristics of the minerals can be determined during microscopic examination. Moreover, this technique is a non-destructive; mineral grains identified under FTIR microscope are available for further study.

TECHNIQUE

Mineralogical ('geochemical') samples do not require any special preparation prior to examination. The sample heavy fraction is placed under a microscope (we used in our studies the Nicolet 380 spectrometer in combination with a Centaurus microscope, THERMO Scientific Co.). The grain size available for the analysis is within the range of 30-500 μm; coarser grains may also be studied as fragments. The technique has proven to be reliable for transparent minerals, whereas opaque grains (*e.g.*, sulphide and ilmenite) are better studied with the aid of other techniques. The standard OMNIC software allows for the collection of IR spectra within only a few minutes, after which time the comparison of spectra obtained with various mineralogical databases is available to the user. The use of standard IR databases, however, may sometimes be limiting because the resulting FTIR spectra relate to single grains, and may differ to that of routine powder IR analysis data (Fig. 1).

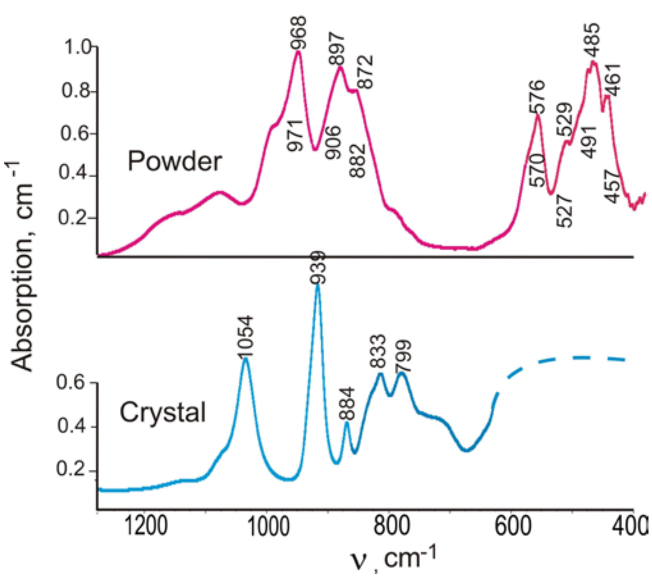

Fig. 1. IR spectra of pyrope garnet obtained from both a powdered sample (top) and a single crystal (bottom).

Table 1 comprises the major IR characteristics of diamond indicator minerals obtained from single crystals.

Table 1. IR characteristics of diamond indicator minerals (single crystals)

Mineral	Wavelengths, cm^{-1}
Diamond	1010, 1100, 1135, 1175, 1280,~1370, **1980, 2030, 2170, 2560, 3580**
Chrome-diopside	**999, 1018, 1050,1183, 1508, 1566, 1954**, 3441, 3639, 3680
Pyrope garnet	799, **877, 934**, 1054, 1379, 1485, 1764
Olivine	813, **844**, 973, **997**, **1087, 1669, 1782, 1834, 1915, 2025**
Chrome spinel	~770
Zircon	**1546, 1596, 1789, 1836, 1871, 1903, 1947**, 3379, 3413
Apatite	**1154, 1416, 1460, 1998, 2077, 2148**, 3527, 3548, 3570

Note: Most characteristics wavelengths are shown in bold

GARNETS

For garnets, the composition of pyralspite varieties can be identified, as well as the Cr content in pyrope. This allows for distinguishing, among orange garnets, of the ultramafic and the eclogitic association garnets.

IR spectra from single garnet crystals exhibit two absorption maxima within the following wavelength ranges: ν_1 from 870 to 942 cm^{-1} and ν_2 from 826 to 884 cm^{-1}. The values of these maxima shift depending upon the cation radii, R^{2+} (Mg, Fe^{2+}, Mn, Ca) and R^{3+} (Al, Fe^{3+}, Cr). In general, the increase of both cation-type radii reflects a decrease in the wavelengths of ν_1 and ν_2 (Fig. 2).

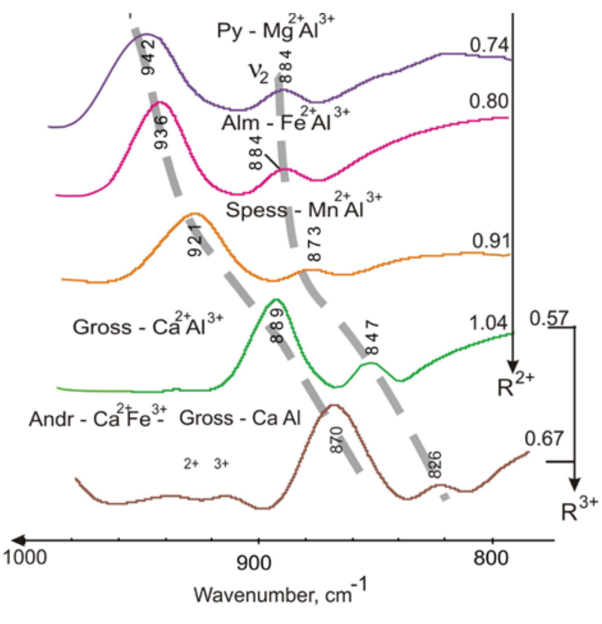

Fig. 2. IR spectra of garnets of differing composition.

The Cr concentration in garnet linearly affects the absorption maximum within the range of 875-890 cm^{-1} (Fig. 3). Using these correlations, it is possible to identify the type of garnet in the sample and to be able to estimate the concentration of Cr in any given grain.

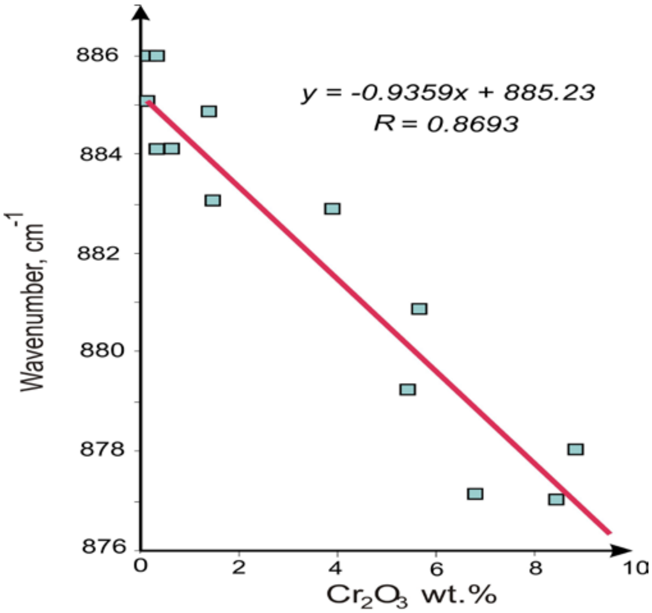

Fig. 3. Dependence of the absorption maxima within the range of 875-890 cm^{-1} on the concentration of Cr in garnet.

The FTIR technique further allows the discrimination of orange, eclogitic almandine-pyrope garnet of kimberlitic origin from garnet that originated in the host metamorphic rock. This task is of particular importance during prospecting within ancient shield areas that may host a wide development of regionally metamorphosed rock formations. Fig. 4 illustrates the IR characteristics of pyrope and almandine-pyrope garnets of differing genesis, that are almost completely indistinguishable by optical means.

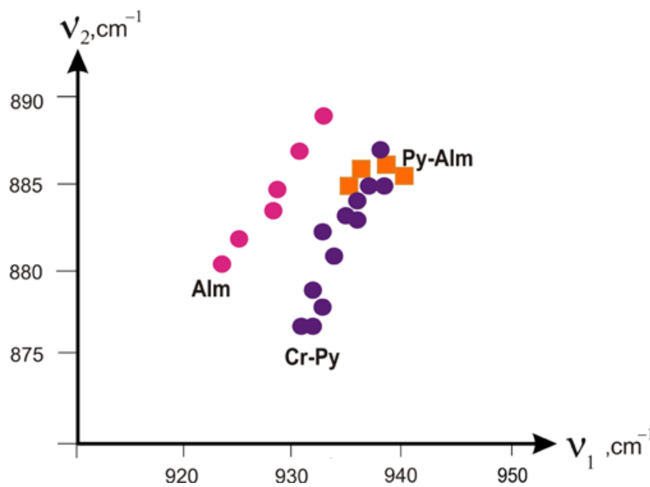

Fig. 4. IR spectral characteristics of pyrope and almandine-pyrope garnets from the Arkhangelsk area and Karelia, Northern Europe.

ZIRCON

During the course of prospecting, kimberlitic zircon is optically quite similar to zircon from other sources, such as granite, pegmatite, nepheline-syenite, *etc*., making prognostication difficult. In contrast, the FTIR spectra of kimberlitic zircon is characterized by the presence of double absorption lines at 3380 and 3420 cm^{-1}, caused by the presence of hydroxyl groups (Woodhed *et al*., 1991), which is non-characteristic for zircon from other sources (Fig. 5). As such, this provides a rapid and simple method of identifying zircon of a kimberlitic origin in the sample analysis.

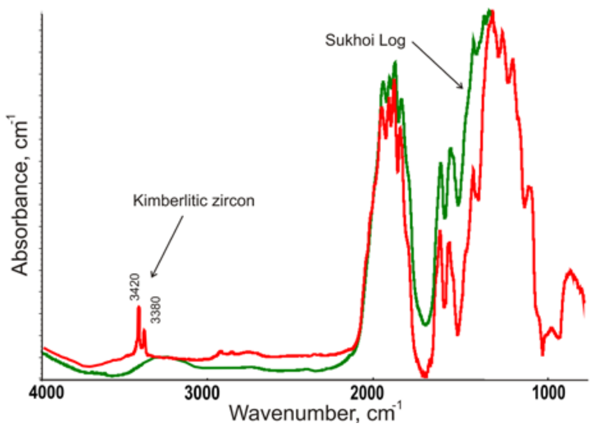

Fig. 5. FTIR spectra of zircon from kimberlite in Northern Yakutia (red) and from granite from the Sukhoi Log gold deposit (green).

USE OF DIAMOND POPULATIONS IN PROSPECTING

Diamond from different kimberlitic localities are typically characterized by different concentrations of nitrogen impurity (N_{tot}) and its aggregation ($\%N_B = (N_B/(N_B+N_A)*100$). The total nitrogen content, most likely, is related to the character and the composition of the diamond-forming media, *e.g.*, peridotitic or eclogitic (*e.g.*, Stachel and Harris, 1997); and the aggregation of nitrogen is the function of temperature of diamond crystallization and the subsequent thermal history of diamond (*e.g.*, Evans, 1992). By these characteristics, six major populations of diamond are now distinguished (Fig. 6).

During the course of prospecting, the emplacement of different diamond populations in alluvial samples in a mapped area can allows for the discrimination of these various diamond sources and further, to outline the location of new ones.

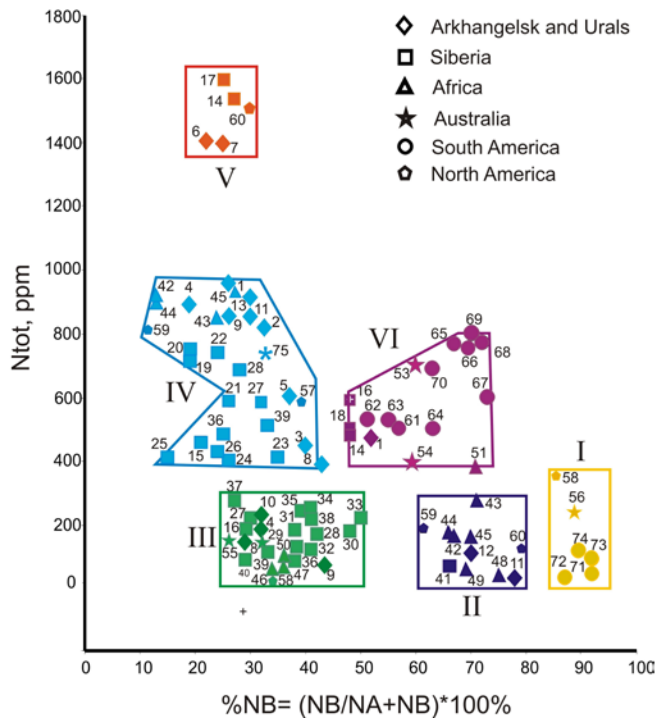

Fig. 6. Populations of diamond (I-VI) based on their average nitrogen characteristics. Numbers indicate the geographical locations of the kimberlites and placer deposits: 1 -Northern Urals, 2 -Middle Urals, 3-13 – Archangelsk (Snegurochka, 4 - Lomonosovskaya, 5 - Karpinsky-I, 6 - Arkhangelskaya, 7 - Pomorskaya, 8 - Pervomayskaya, 9 - Volchya, 10 - Grib, 11 –Yurasskaya, 12 - Stepnaya, 13 - Ermakovskaya), 14-41 - Yakutia (14 - Bulkur, 15 - Conglomeratovi, 16 – Molodo, 17 - Kholomolookh, 18 - Billyakh, 19 - Malokuonapskaya, 20 - XXIII Congress CPSU, 21 - Sputnik, 22 – Internationalnaya, 23 – Mir, 24 - Solur, 25 – Irelyakh, 26 - Gornyi, 27 – Zarnitsa, 28 - Udachnaya, 29 - Aykhal, 30 - Molodost, 31 – Sytykanskaya, 32 – Dalnaya, 33 – Prognoznaya, 34 – Krasnopresnenskaya, 35 – Komsomolskaya, 36 – Yubileynaya, 37 – Leningrad, 38 – Muna, 39 – Tyung, 40 – Zapolyarnaya, 41 – Poiskovaya), 42- - South Africa (42 – Orapa, 43 – Jwaneng, 44 – Venetia, 45 – Premier, 46 – Finsh, 47 – Roberts Victor, 48 - Jagersfontein, 49 – Koffifontein), 50 – Birrim, 51 – Namibia, 53-56 – Australia (52 – Ektor, 53 – Wellington, 54 – Bingara, 55 – Copeton, 56 – Argyle), 57-60 – Canada (57 – DO-27, 58 – Panda, 59 – Point Lake, 60 – K -252), 61-64 and 71-74 – Brazil (61 – Cor. Criminosa, 62 – Cor. Esp. Santo, 63 – Grota do Pimpim, 64 – Cor. Imbe, 71 – Cor. Chicora, 72 – Rio Soriso, 73 – Sao Luiz, 74 – Vermelho), 65-70 – Venezuela (65 - Los Coquitos, 66 – Guaniamo, 67 – La Centella, 68 – Chihuahua, 69 – Quebrada Grande, 70 – Ringi-Ringi), 75 – Momeik (Myanmar).

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