

MINIDENT: A DATA BASE FOR MINERALS AND A COMPUTER PROGRAM FOR THEIR IDENTIFICATION

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ABSTRACT

MINIDENT is a program for interactive mineral identification and mineral data base management, rewritten in FORTRAN 77. Data have been stored for about 4000 mineral groups, species and varieties. These data comprise: composition, optical properties, symmetry, cell dimensions, density, Vickers and Mohs hardness, d -values and relative intensities for the strongest five X-ray powder-diffraction lines, the PDF number, polymorphs if any, occurrences, localities, year first described and sources of the data. As yet, however, not all minerals have data stored for all properties. The program will generate a list of minerals whose properties lie within input ranges for an unidentified mineral or display and rank twenty possible identities for an unknown. It can also be used to tabulate chosen properties of matched minerals or to tabulate minerals (in the data base) that have certain specified properties. Tests using data for known species to simulate unidentified minerals show high reliability, given accurate input information, and surprising success even with qualitative input data. The MINIDENT software currently uses about 400 kbytes of memory, and the data base used in mineral identification uses a further 10 Mbytes. Running time for a typical identification procedure ranges from about 0.05 to 3.0 seconds of CPU time on the AMDAHL 580/FF mainframe computer, on which the program has been developed. The cycle time of this computer is about 23 ns.

Keywords: Fortran 77, computer program, data base, mineral composition, mineral identification.

SOMMAIRE

MINIDENT désigne un programme d'ordinateur pour l'identification des minéraux et le maniement des données minérales servant à cette fin. Ce programme a été ré-écrit en FORTRAN-77. Les données rassemblées concernent environ 4,000 espèces minérales, y compris variétés et familles de minéraux. Ce sont: composition chimique, optique, symétrie, maille, poids spécifique, dureté (Vickers et Mohs), distances inter-réticulaires (d) et intensités relatives des cinq raies les plus intenses du cliché X de poudre, numéro de la fiche PDF, formes polymorphes, modes de gisement localités, année de la première description et sources des données. A présent les propriétés ne sont pas encore toutes mises en place pour tous les minéraux inclus. Ce programme peut fournir une liste de minéraux dont toute propriété numérique a une valeur comprise entre les limites déterminées sur l'échantillon étudié ou bien citer et ranger, en ordre de probabilité, vingt identifications possibles pour tel échantillon. Il est également capable de construire un tableau soit de certaines propriétés choisies sur deux échantillons assortis, soit des minéraux (déjà dans le système) qui possèdent

certaines propriétés. Les essais fondés sur les données de minéraux connus en vue de reproduire les propriétés de l'échantillon à identifier se sont avérés dignes de confiance, dans la mesure de l'exactitude de l'input; mais même avec un input qualitatif, le taux de réussite est surprenant. Le MINIDENT utilise à présent environ 400 kbytes de mémoire (software) et 10 Mbytes de plus pour l'identification des minéraux. Le temps requis pour une détermination d'un minéral varie, typiquement, de 0.05 à 3.0 secondes (temps CPU) sur ordinateur AMDAHL 580/FF, instrument qui a servi à développer le programme. La durée du cycle est d'environ 23 ns.

Mots-clés: Fortran-77, ordinateur (programme d'), banque de données, composition des minéraux, détermination.

INTRODUCTION

The identification of minerals has always been one of the recurring tasks of earth scientists involved in such diverse specializations as mineralogy, crystallography, geochemistry, experimental mineralogy, petrology, ore mineralogy, mineral exploration, mineral beneficiation, clay mineralogy and even meteoritics. Traditionally, the approaches to identification have been principally through the determination of optical properties and characterization on the basis of X-ray powder-diffraction patterns.

Although optical techniques have the advantage of being nondestructive, generally X-ray-diffraction methods have proved the more powerful and unequivocal. In recent years the power of the computer has been added to the X-ray-diffraction techniques, and sophisticated programs have been developed that permit identifications on the basis of input information on d -values and line intensities. However, although expert practitioners of the technique can produce satisfactory powder photographs from extraordinarily small quantities of material, sampling selectivity is often inadequate to deal with intergrowths on a scale of a few μm or less, such as are commonly encountered in natural rocks. In the optical area, the NISOMI system (Atkin & Harvey 1979, 1982) is an example of the application of a microcomputer system to the identification of opaque minerals on the basis of a careful measurement of their reflectance at 16 different wavelengths. Once again, however, it is seldom possible to resolve satisfactorily the finer-grained intergrowths in terms of the reflectances of the component minerals.

Although such techniques have been applied widely in many of the fields mentioned above, over the last decade or two optical and X-ray information has been augmented more and more frequently by data on chemical composition. These data have been obtained principally using the electron microprobe and other microbeam techniques, which have the virtue of being virtually nondestructive and spatially highly selective. Such information, as well as becoming more abundant, has become more accurate as the procedures of microanalysis have been further and further perfected. The development of sophisticated computer software and hardware has contributed greatly to the refinement of microanalytical techniques. However, the next logical step, that of using the power of the modern computer to assist in identifying a mineral that has been analyzed, has not been taken. MINIDENT was originally conceived as a compositional data base that would fulfill this role. However, the advantage of integrating the compositional approach with others based on optical, X-ray and additional properties, was quickly realized. An on-going project involving construction of a substantial data base and creation of programs required for the identification of minerals was undertaken.

The first working version was described by Smith & Leibovitz (1984). That FORTRAN IV version of MINIDENT used a data base that contained only very limited data for some 2000 minerals. The entry of real analytical data for so many minerals represents a major undertaking in itself. It was found, however, that remarkably good results could often be obtained using chemical compositions calculated by the program itself from formulae that had been input; most of the examples of the applications reported by Smith & Leibovitz (1984) used such calculated compositional data. Notwithstanding these successes, it became apparent that in some cases the calculated compositional data did not produce unambiguous mineral identifications, and frequently the correct mineral was not at the top of the list of probable identities. The task of entering real compositional data for as many minerals as possible was therefore undertaken as a matter of urgency. Concurrently, basic data were entered for as many of the missing mineral species as possible, and the entire program was rewritten in FORTRAN 77. This version of FORTRAN is now more widespread and is considered to be more portable, *i.e.*, less system-dependent. It provides a number of important facilities not available in FORTRAN IV. The modified data base and program form the subject of the present communication.

THE DATA-BASE PARAMETERS

The problem of mineral classification had to be faced in the construction of the data base. Although

the division into classes, groups, species and varieties is widely used, the situation is not always so simple and straightforward. Terms such as family, supergroup, subgroup and subspecies have all been used. To take an example, cleavelandite is a variety of albite that might be considered to be a member of either the plagioclase or the alkali feldspar groups, both of which belong to the feldspar supergroup, or perhaps feldspar family, which falls in the tectosilicate class of the silicate minerals. Although possible levels of nomenclature are less complex for some other minerals, the basis for the use of a particular term of classification is not always well defined. Thus in certain cases, all minerals within a group have the same structure (*e.g.*, the garnets). In other groups the structures are similar (*e.g.*, the plagioclase feldspars), whereas in yet other groups, such as the zeolites (which are sometimes referred to as a family), the structures may be very different although they retain certain features in common.

It was eventually decided for the purposes of this data base to adopt a primary division into "types" and species. The term *type* is used here to refer to a fundamental division on the basis of chemical composition, *e.g.*, silicates, carbonates, oxides, *etc.* It has been used to avoid the implications of other terms such as class, which has been used in a more restricted sense, for example, the nesosilicate, inosilicate and cyclosilicate classes of the silicate minerals. The works of Hey (1962, 1963) and Ferraiolo (1982) have been used extensively in allotting minerals to these types. If a mineral has obviously mixed character, it can be assigned to two different types so that a search based on either would bring the mineral to light. Thus, for example, the mineral heidornite, which has the formula $\text{Na}_2\text{Ca}_3\text{B}_3\text{O}_8(\text{SO}_4)_2\text{Cl}(\text{OH})_2$, would be listed under the borates and sulfates, rather than chlorides and hydroxides, since Cl and (OH) clearly play a subordinate role to the borate and sulfate radicals. A hierarchical scheme of classification has been developed using other division such as varieties, polytypes, subspecies, series, subgroups, groups, families, subclasses and classes. So far, however, it has been implemented only to a very limited extent (*e.g.*, for the feldspars). When it is more complete, it should be of value in permitting ranges of properties within the various divisions to be examined.

At the time of writing, the MINIDENT data base includes information for approximately 4000 mineral groups, species and varieties. Of these, about 3250 are represented by real analytical data. The following parameters have been entered for as many of the minerals as possible with the time and resources available:

1. Name
2. Mineral type
3. Formula

4. Composition (concentrations of all elements present in weight %)
5. Co-ordination number of the cations
6. Indices of refraction
7. Optic axial angle ($2V\gamma$)
8. Orientation of the optic axial plane (for monoclinic minerals)
9. Color (pleochroic scheme)
10. Dispersion
11. System of symmetry
12. Space group
13. Unit-cell dimensions and angles
14. Strongest five X-ray powder-diffraction lines, in order of decreasing relative intensity
15. Number of powder-diffraction file (PDF) in the JCPDS system
16. Density
17. Mohs hardness
18. Vickers hardness number
19. Reflectance at wavelengths of 470, 546, 589 and 650 nm
20. Typical occurrences
21. Geographical locations of samples for which data are stored
22. Literature sources from which sample data were obtained
23. Polymorphs
24. Year mineral was first described
25. Remarks

Certain of the above parameters (for example the space group, the PDF file number, locations of samples, *etc.*) are of no use in identification of unknowns. However, it was felt that this information would be of value. In future other data fields may be added. Also, it will be clear that data will remain absent in certain fields for many minerals. For example, the reflectance values and Vickers hardness numbers will be available, in general, only for ore minerals. Similarly, the indices of refraction will not be available for many of the ore minerals.

TYPES OF DATA IN THE DATA BASE

Four different types of information have been used to construct the data base. These are: mineral data, sample data, general data and compiled data. Mineral data are those that are constant and thus common to all samples. Some examples are: name, formula, symmetry, space group, PDF number, polymorphs and the year first described. On the other hand, sample data pertain to particular samples of a mineral, and many such samples may be included in the data base. Some examples are composition, indices of refraction, $2V$, color, unit-cell dimensions and angles, density, reflectances and Vickers hardness numbers. In many instances literature sources used in constructing the data base present only minimum and maximum values for mineral parameters,

Page: 1 Compiled/Mineral Data Display

Record: 1076 Name: KAERSUTITE				Date: 16:21:19AUG 2, 1985								
Formula: NaCa2(Mg,Fe)4TiSi6Al2O22[OH]2												
Symmetry: Monoclinic			Space Group: C2/m			JCPDS: 17-0478			Dispersion: R>V			
Type: SILICATES			Year First Described: 1884			Samples: 10			Generals: 2			
						Total Samples: 10						
El	Wt Min	Wt Ave	Wt Max	Std Dev	At Prop	Coord	a	b	c	Alpha	Beta	Gamma
O	42.417	42.836	43.261	0.281	23.913*							
Si	17.903	18.579	19.380	0.443	5.908	4	9.900	18.210	5.400	90.000	106.000	90.000
Fe	6.753	8.977	10.992	1.425	1.436	6 8						
Ca	7.433	8.175	9.205	0.620	1.822	8	n(alpha)	n(beta)	n(gamm)	Density	VHN	MOH
Al	5.621	7.062	9.061	0.946	2.338	4 6	1.600	1.690	1.700	3.153		5.0
Mg	6.007	6.972	8.250	0.656	2.561	6	1.682	1.706	1.721	3.223		5.5
Ti	2.710	4.057	6.193	1.041	0.757	6	1.689	1.741	1.772	3.28		6.0
Na	1.291	2.108	2.834	0.454	0.819	12 8	R(470)	R(546)	R(589)	R(650)	2V(gam)	OAP
K	0.490	1.144	2.324	0.499	0.261	12					98.0	/(010)
F	0.000	0.185	0.420	0.189	0.087*						101.643	
Mn	0.062	0.125	0.263	0.060	0.020	6					114.0	
H	0.013	0.105	0.246	0.072	0.934	6	C(alpha)	C(beta)	C(gamm)	d-vals.		
Ba	0.000	0.027	0.054	0.002	0.002	12	Br Y1	Rd	D Rd Br	2.69		
Ni	0.000	0.024	0.047	0.004	0.004	6	L Y1 Br	Rd Br	Gn Br	3.11		
P	0.000	0.013	0.026	0.004			Y1		D Br	8.38		
							L Y1			3.36		
										2.548		
100.39							40.865					
Collection number(s):												
Polymorphs:												
Remarks: Amphibole group (titanian hornblende).												
Occurrence: Commonly occurs in camptonites. Also in monzonite and monchiquite. In volcanic rocks it appears in trachybasalts, basaltic dykes & scoria. Found as cognate xenoliths in trachyte. Often occurs as phenocrysts.												
Location(s): Boulder Dam, Arizona. Wart Holm, Copinshay, Orkneys. Takenotsoji, Japan. Tikaishi, Dogo, Oki islands, Japan. West of Kakujo-san, Gonoura-machi, Japan. Dunedin, New Zealand. Skaergaard, East Greenland. Kaersut, Greenland. Yohodo, Korea. Tyaki, Morotu, Sakhalin, U.S.S.R.												

FIG. 1. Example of the listing of compiled data for the mineral kaersutite.

these having been determined from observations on many different samples. Wherever such data are used, they are referred to as general data. Note in this context that the data base for a given mineral may contain general data from more than one source. General data are not necessarily the most useful but are often the only kind presented. With the exception of composition, the examples of general data are exactly the same as those given above for sample data.

The last category of data is that used by MINIDENT for identification purposes. These are compiled data, calculated from the data that have been entered into the MINIDENT data base as sample or general data. Maxima, minima, means and, in the case of compositions, standard deviations are determined. Where insufficient real compositional information has been entered, theoretical maxima and minima are calculated by the program from the formula that has been entered. The mean values are then replaced by values midway between the minimum and maximum, and standard deviations are then omitted. Figure 1 is an example of the listing of compiled data for the mineral kaersutite. MINIDENT will generate on request such a tabulation for any of the minerals in the compiled data base. A hard copy of the compiled data base is generated after every major update and kept on hand for reference purposes. However, since the data base occupies 10 binders (more than 4000 pages), unnecessary regeneration in this form is avoided as much as possible.

To the above kinds of data might be added a fifth, data for an unidentified mineral (UM). This is the information about a sample that is being investigated that a user will enter into MINIDENT for identification purposes. Throughout the rest of the paper, the term UM data will be used with this meaning.

SOURCES OF INFORMATION FOR THE DATA BASE

Many different sources have been used to obtain the information that has been incorporated into the data base. In particular, Deer *et al.* (1962, 1963, 1978, 1982), Dietrich (1969), Embrey & Fuller (1980), Fleischer (1983), Fleischer *et al.* (1984), Henry (1977), Hey (1962, 1963), Pierrot (1979), Roberts *et al.* (1974) and Uytendogaardt & Burke (1971) have been particularly important sources. All new minerals reported in *The American Mineralogist* since 1966 have been incorporated, and *Mineralogical Abstracts* has been used extensively to track down additional information for many minerals. Certain minerals or mineral groups (e.g., the clay minerals) have been covered in greater detail than others because specialized data bases intended originally for other specific uses have been incorporated into MINIDENT.

The powder-diffraction data that have been included are based on those in the mineral section of the JCPDS manual for 1984. Where data are not given there, wherever possible, data have been obtained from elsewhere in the literature. Optical properties have been based largely on those given by Tröger (1979), Winchell (1956), Winchell & Winchell (1951), Roberts *et al.* (1974), Dietrich (1969), with values for reflectance coming mainly from Henry (1977).

THE MINIDENT PROGRAM

In addition to the data base discussed above, the MINIDENT package includes programs designed to enable users to identify minerals and to tabulate their properties. Two alternative approaches are embodied in the mineral identification software. These are selected by issuing one or other of the commands MATCH and IDENTIFY.

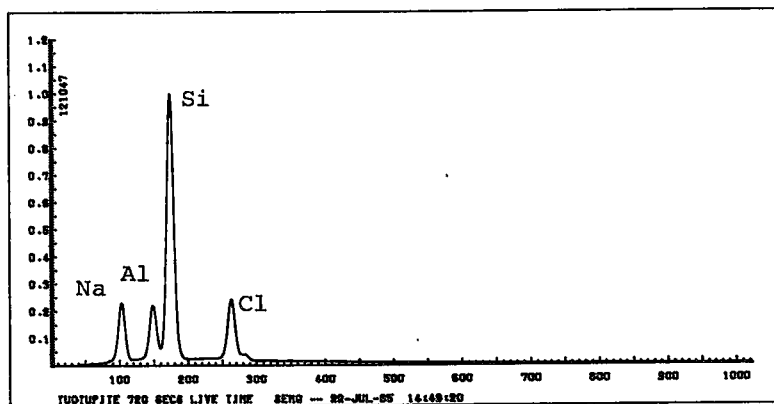


FIG. 2. Energy-dispersion spectrum for the mineral tugtupite.

The MATCH command searches the data base for every mineral that exactly matches the input data and permits the user to list these minerals in alphabetical order. To allow some latitude in the matching of an unidentified mineral with minerals in the data base, UM data are normally entered as a range. For example, the input Si = 18-22 would indicate that, to be considered as a match, a candidate mineral would have to contain between 18 and 22 wt. % of the element Si. Any minerals lying even slightly outside this range will be rejected. As many additional stipulations as are wished may be added to minimize the number of matching minerals that will be listed. If the accuracy of UM compositional data is dubious, then the qualitative terms major (3-100%), minor (0.1-5%) and trace (<1%) may be entered. The overlap in these ranges is intended to allow for

different users' interpretations of the data and of these qualitative terms.

The alternative command IDENTIFY results in a quite different approach, in which the most *likely* matches are selected on the basis of all input data. Whereas the MATCH procedure will categorically reject any mineral for which *any* input parameter lies outside the known ranges, IDENTIFY simply assigns demerit points for the mismatches. Up to 20 of the most likely matches may eventually be listed, and the matching index for each of these shown. This Total Matching (TM) index is complex and is based on both the degree of match or mismatch and the importance of the parameters being matched.

In its original conception, MINIDENT was intended to identify minerals on the basis of composition. Although, as has been explained, this basis

TABLE 1

)Ident command"? unknown|w O=major|w Na=major|w Al=major|w Si=major|w Cl=major|save|match
)3742 minerals examined, 0 ignored, 3727 not matched, 15 matched.
)Ident command"? tabulate unknown name formula w O w Na w Al w Si w Cl

Name	Formula	O	Na	Al	Si	Cl
unidentified sample		3.0 100.0	3.0 100.0	3.0 100.0	3.0 100.0	3.0 100.0
AFGHANITE	(Na,Ca,K)8(Si,Al)12O24(C1,S04,C03)3:H2O	42.753	9.485	13.499	14.686	4.428
DAVYNE	(Na,Ca,K)8Al6Si6O24(C1,S04,C03)2-3	41.302	9.488	14.469	15.061	5.293
DELHAYELITE	(Na,K)10Ca5Al6Si13O28O(C12,F2,S04)3:18H2O	47.338	2.374	4.88	24.587	3.91
DIPYRE	Na4Al3Si9O24C1	45.841	5.759	12.524	25.021	2.197
FRANZINITE	(Na,Ca)7(Si,Al)12O24(S04,OH,C03,C1)3:H2O	45.521	8.531	13.342	15.164	0.36
GIUSEPPETTITE	(Na,K,Ca)7-8(Si,Al)12O24(S04,C1)1-2	43.56	10.66	15.115	15.542	0.78
HACKMANITE	Na8Al6Si6O24C12	41.555	18.46	16.832	17.34	6.333
LAZURITE	(Na,Ca,K)7-8(Al,Si)12(O,S)24(S04,C12,[OH]2)	43.501	14.429	14.613	15.201	0.47
LIOTTITE	(Na,Ca,K)8(Si,Al)12O24(S04,C03,C1,OH)4:H2O	44.075	5.913	13.189	14.262	2.57
MARIALITE	3NaAlSi3O8:NaC1	45.622	7.849	10.979	27.46	3.095
MICROSOMITE	(Na,Ca,K)7-8(Si,Al)12O24(C1,S04,C03)2-3	46.172	8.249	14.025	14.21	4.5
SCROFANITE	(Na,Ca,K)9(Si,Al)12O24([OH]2,S04,C03,C12)3:7H2O	44.734	12.241	13.2	15.454	0.59
SCAPOLITE	(Na,Ca,K)4Al3(Al,Si)3Si6O24(C1,F,OH,C03,S04)	45.949	5.584	13.986	23.968	2.106
SODALITE	Na8Al6Si6O24C12	40.638	17.507	17.03	17.271	6.021
TUGTUPITE	Na4BeAlSi4O12C1	43.064	18.094	6.274	23.846	6.66

TABLE 2

)Ident command"? unknown|w O=major|w Na=major|w Al=major|w Si=major|w Cl=major|save|identify
)3742 minerals examined, 0 ignored, top 20 identified.
)Ident command"? tabulate unknown len 13 name tm len 44 formula w O w Na w Al w Si w Cl

Name	TM	Formula	O	Na	Al	Si	Cl
unidentified sample			3.0 100.0	3.0 100.0	3.0 100.0	3.0 100.0	3.0 100.0
DAVYNE	100.0	(Na,Ca,K)8Al6Si6O24(C1,S04,C03)2-3	41.302	9.488	14.469	15.061	5.293
AFGHANITE	100.0	(Na,Ca,K)8(Si,Al)12O24(C1,S04,C03)3:H2O	42.753	9.485	13.499	14.686	4.428
HACKMANITE	100.0	Na8Al6Si6O24C12	41.555	18.46	16.832	17.34	6.333
MARIALITE	100.0	3NaAlSi3O8:NaC1	45.622	7.849	10.979	27.46	3.095
MICROSOMITE	100.0	(Na,Ca,K)7-8(Si,Al)12O24(C1,S04,C03)2-3	46.172	8.249	14.025	14.21	4.5
SODALITE	100.0	Na8Al6Si6O24C12	40.638	17.507	17.03	17.271	6.021
TUGTUPITE	100.0	Na4BeAlSi4O12C1	43.064	18.094	6.274	23.846	6.66
LIOTTITE	100.0	(Na,Ca,K)8(Si,Al)12O24(S04,C03,C1,OH)4:H2O	44.075	5.913	13.189	14.262	2.57
DELHAYELITE	99.9	(Na,K)10Ca5Al6Si13O28O(C12,F2,S04)3:18H2O	47.338	2.374	4.88	24.587	3.91
DIPYRE	99.9	Na4Al3Si9O24C1	45.841	5.759	12.524	25.021	2.197
SCAPOLITE	99.9	(Na,Ca,K)4Al3(Al,Si)3Si6O24(C1,F,OH,C03,S04)	45.949	5.584	13.986	23.968	2.106
ZEOLITE	99.6	(Na,K,Ca,Ba)(Al,Si)2[OH]2:7H2O	44.434	50.0	43.539	43.756	
FERSMITE	99.3	(Ca,Ce,Na)(Nb,Ta,Ti)2(O,OH,F)6	14.726		3.881		
NOSEAN	99.3	Na8Al6Si6O24S04	45.455	15.742	14.9	16.907	0.997
TUNISITE	99.1	Na3Ca2Al4[CO3]4[OH]8C1	60.116	3.539	16.83	0.5	5.303
ZUNYITE	99.1	Al13Si5O20(OH,F)18C1	51.381	1.076	30.088	11.265	4.8
MIZZONITE	99.0	[Na]0.8-2[Ca]2-3.2[Al]4.5-5.4[Si]6.6-7.5...*	46.7	2.944	13.893	22.216	0.62
JUSITE	99.0	(Ca,Na,K)5(Si,Al)6O15:5H2O	49.252	9.47	13.337	13.733	
LEIFITE	99.0	Na2(Si,Al,Be)7(O,OH,F)14	51.824	9.199	5.081	33.936	
HERSCHELITE	99.0	(Na,Ca,K)AlSi12O6:3H2O	55.915	6.521	11.241	20.74	

* Formula truncated.

TABLE 3

TUGTUPITE COMPOSITION (WT.%)			
	(1)	(2)	(3)
H		n.s.	0.17
Be		1.92	1.92
O	40.71*	41.43	42.76
Na	18.06	18.83	17.97
Mg		n.d.	0.06
Al	6.32	5.78	6.23
Si	27.06	24.61	23.69
S		0.02	0.17
Cl	7.85	7.41	6.62
Ca		n.d.	0.18
K		n.d.	0.22
Fe		n.d.	
Ga		n.s.	0.01
TOTAL	100.00	100.00	100.00

(1) Semi-quantitative electron probe analysis processed by in-house program "EDARDI".

(2) Quantitative analysis processed through EDATA2 (Smith & Gold, 1979); recalculated to 100% from analytical total of 99.62% (Be fixed at known value).

(3) Information available on actual composition of tugtupite - average of literature analyses recalculated to 100%.

n.d. - not detected. n.s. - not sought.

* - calculated by difference from 100%.

has been broadened to embrace many other properties, a bias toward composition has been retained. Thus in calculating the matching indices, greater weight is placed on the correctness of a compositional matching index (CM) than on the other properties match (OPM). A third index, the information matching index (IM), is based upon the proportion of the properties entered for an unknown that were matched with the information in the data base. As the data base becomes more and more complete, the importance of the IM index will decline. The total matching index (TM) is a weighted combination of the preceding three indices. It should be noted that only those parameters of an unidentified mineral for which data are entered will affect the matching indices. Thus if no compositional data at all were available and perhaps only optical or X-ray data (or both) were entered, an excellent TM index could still be obtained for a particular mineral in the data base.

Of these two approaches to mineral identification, the MATCH procedure will generally lead most quickly to a positive identification or to the largest reduction in the number of possibilities, provided that ample data of good quality are input. It should be noted again, however, that the input of erroneous data or of data with an inadequate margin of uncertainty specified will cause MATCH to fail. For example if the Mohs hardness were entered as 4-5, and the value stored in the compiled data base is 5.5, then that mineral will be excluded from the list of possibilities printed.

Where few data are available or where the data are qualitative in nature, the IDENTIFY procedure will commonly be found the most useful. This proce-

dure can also be called upon to rank the minerals that have been output by MATCH, in order of probability. This is a relatively simple and comparatively inexpensive task once the list of possibilities has been greatly reduced by use of MATCH.

Electron-microprobe data are now very common and often of high quality. Moreover, the advent and perfection of the energy-dispersion spectrometer have further increased the amount of information that is obtained, not only quantitative but also semiquantitative and qualitative data. Because of the importance placed on compositional matching, a special facility has been included in the program whereby the listing of analytical data output by the data-processing and matrix-correction software of an electron microprobe can be entered directly for use by the MINIDENT MATCH or IDENTIFY procedures without the need for intervention by the user. At present, compatibility with the output of EDATA2 (Smith & Gold 1979) has been established and tested because that program is capable of the simultaneous integrated processing of energy- and wavelength-dispersion electron-microprobe analytical data. However, with very minor modification, the output from most such programs should be suitable for entry into these MINIDENT procedures.

For earth scientists (and others) using an energy-dispersion spectrometer in a qualitative role, MINIDENT offers the possibility of determining conveniently and rapidly what are either the possible or the most likely identities of the mineral being examined. This can be done by entering MAJOR, MINOR or TRACE for the concentrations of each of the elements observed in an energy-dispersion spectrum, or alternatively entering approximate concentrations with due allowance being made for analytical uncertainties.

The MINIDENT data base, in addition to the fields previously described, also contains a synonymy. Entry of a synonym will result in the generally accepted name being supplied. Entry of a discredited mineral name will result in a message to this effect being printed, usually together with a very brief explanation or reference. If information about a mineral is requested by use of the synonym (e.g., dis-thene for kyanite), a message will be printed giving the accepted name, and then the data requested will be listed.

EXAMPLES OF APPLICATIONS OF MINIDENT

As an illustration of the different possible approaches to mineral identification by MINIDENT, data for tugtupite $\text{Na}_4\text{BeAlSi}_4\text{O}_{12}\text{Cl}$ have been entered as if it were an unidentified mineral. This mineral was chosen because it is unusual and therefore unlikely to be recognized by the average user on the basis of its hand-specimen properties or its

TABLE 4

)Ident command""? unknown|w O=35-45|Na=16-20|w Al=5-8
)Unknown input""? w Si=24-30|w Cl=6.3-9.3|save|match
)3742 minerals examined, 0 ignored, 3735 not matched, 7 match
)Ident command""? tab unknown name tm w O w Na w Al w Si w Cl

Name	TM	O	Na	Al	Si	Cl
unidentified sample		35.0 45.0	16.0 20.0	5.0 8.0	24.0 30.0	6.3 9.3
FRANZINITE	67.8	45.521	8.531	13.342	15.164	0.36
GIUSEPPETTITE	71.0	43.56	10.66	15.115	15.542	0.78
LAZURITE	60.4	43.501	14.429	14.613	15.201	0.47
LIOTTITE	61.2	44.075	5.913	13.189	14.262	2.57
MICROSOMMITE	70.7	46.172	8.249	14.025	14.21	4.5
SACROFANITE	73.8	44.734	12.241	13.2	15.454	0.59
TUGTUPITE	100.0	43.064	18.094	6.274	23.846	6.66

optical properties, or, for that matter, on the basis of its energy-dispersion spectrum (where the presence of Be will not be apparent, except in the unlikely circumstance that a high-quality 'windowless' detector is used). Figure 2 shows the spectrum recorded on an Ortec EEDS II energy-dispersion system attached to an ARL SEMQ microprobe operated with a 15 kV electron-accelerating potential. It is a simple matter for an analyst to identify the peaks present, and even very limited experience would be sufficient for an analyst to recognize that all the labeled elements are present in major proportions. These elements were entered into the MATCH procedure, and the results obtained are shown in Table 1. Note that trace and even minor elements should not be used in the MATCH procedure to avoid the possibility of a mineral being rejected simply because none of the samples forming the data base happened to contain such relatively unimportant constituents. When the same data are put through the IDENTIFY procedure, trace and minor element concentrations can be included; their presence or absence in data-base samples will not have a disproportionate effect on the calculated matching indices because weightings are reduced as concentrations decrease. Table 2 shows the results of processing the qualitative data for tugtupite through IDENTIFY.

Table 3 shows the results obtained for tugtupite when the acquired spectrum has been processed through an in-house program for semiquantitative analysis. This program takes a very simplified approach to background fitting and overlap correction and makes no attempt to calculate matrix corrections. It is found that for most silicates the results obtained are accurate to about $\pm 15\%$ relative, sometimes being worse, but often appreciably better. Note also that Be will not appear in the results because the BeK radiation is too soft (*i.e.*, of far too low an energy) to pass through the detector window, the Au contact-surface film and the Si dead layer. The results of MATCH and IDENTIFY, with the data in Table 3 as input, are shown in Tables 4 and 5.

TABLE 5

)Ident command""? unknown
)Unknown input""? w O=40.71
)Unknown input""? w Na=18.06
)Unknown input""? w Al=6.32
)Unknown input""? w Si=27.06
)Unknown input""? w Cl=7.85
)Unknown input""? save
)Ident command""? identify
)3742 minerals examined,
)0 ignored, top 20 identified.
)Ident command""? tabulate -
)-""? unknown name tm

Name	TM
unidentified sample	
TUGTUPITE	77.9
JADEITE	70.8
ELISAVETINSKITE	68.1
SAPPHIRINE-1TC	67.6
ALKALI-FELDSPAR	66.1
SCHULENBERGITE	65.6
PLAGIOCLASE	64.5
TETRAKALSILITE	64.3
FERRO-ANTHOPHYLLITE	62.8
MAGNESIO-ANTHOPHYLLITE	62.8
SPODIOPHYLLITE	61.4
MOUNTAINITE	61.2
CLINOFERROSILITE	61.1
CLINOHYPERSTHENE	61.1
GIUSEPPETTITE	60.4
KARPINSKITE	58.8
SACROFANITE	58.4
MCGILLITE	56.7
SODALITE	56.2
SCAPOLITE	55.9

It should be noted that in Table 4, for example, the element concentrations are the averages or means for the minerals listed. In the case of minerals for which there are no real analytical data stored, these values will simply be the means of the maxima and minima calculated from the formula. In the case of minerals where there are only a few real data, the

calculated means are replaced by the actual averages, but the calculated minima and maxima are retained. In Table 4 it will be observed that tugtupite is the only mineral for which the mean concentrations are consistently close to the input values. The TABULATE facility also permits minimum and maximum values to be displayed. In the interest of conserving space, this has not been done in the tables reproduced here.

Results of a fully quantitative analysis of the same material processed through EDATA2 are also shown in Table 3. Here the Be content was fixed at a known value. However, the common procedure of assuming that the difference between the analytical oxide total and 100% corresponds to water could have been taken equally well. Such a false assumption will have only very minor effects on the matrix corrections and the accuracy of the analysis for other elements because the BeO actually making up the missing material and the H₂O assumed are of similar average atomic number; neither would be involved significantly in either absorption or fluorescence corrections. In addition to entering the quantitative analytical data here, the strongest X-ray-diffraction lines measured from a powder photograph by an undergraduate student have been added, and the combined input has been processed through MATCH and IDENTIFY to give the results in Tables 6 and 7.

The presence of a doublet, not recognized by the student, resulted in the omission of one of the strongest five lines, a significantly larger error than would otherwise have been made in the *d* values for the one component of the doublet that was measured, and an error in the sequence of the strongest lines. This can be considered in a sense to be a 'worst case' in that normally a much more experienced mineralogist would be making the observations. Furthermore, all of the *d* values were obtained from a powder photograph using a simple plastic overlay scale, and the relative intensities were estimated visually. Subsequent tests using the X-ray data alone showed that tugtupite was, nevertheless, one of the most likely of a handful of possibilities listed by IDENTIFY. Finally, optical data obtained by the same student (indices of refraction, symmetry and color) were added to the data, which were then reprocessed to give the results shown in Tables 8 and 9.

As can be seen from this series of illustrations, MINIDENT always included tugtupite as one of the possibilities and IDENTIFY quickly homes in on it as a highly probable candidate as the quality and amount of data entered are increased.

As mentioned earlier, MINIDENT offers the possibility of tabulating information from the data base which, for some reason, is of interest to the user. As an example of this application, Table 4 shows the name plus O, Na, Al, Si and Cl concentrations as

TABLE 6

```
)Ident command"? unknown|w O=41.44|w Na=18.83|w Al=5.5-6.0
)Unknown input"? w Si=24-25|w S=0.02|w Cl=7.2-7.6|save|match
)Element S with weight of 0.020% has been ignored (CUTOFF=1.0%).
)3742 minerals examined, 0 ignored, 3736 not matched, 6 matched.
)Ident command"? tab unknown name tm w O w Na w Al w Si w S w Cl
```

Name	TM	O	Na	Al	Si	S	Cl
unidentified sample		41.026 41.854	18.642 19.018	5.5 6.0	24.0 25.0	0.02 0.02	7.2 7.6
GIUSEPPEITITE	62.7	43.56	10.66	15.115	15.542	3.973	0.78
LAZURITE	49.1	43.501	14.429	14.613	15.201	6.899	0.47
LIOTTITE	51.7	44.075	5.913	13.189	14.262	3.468	2.57
MICROSOMMITE	47.0	46.172	8.249	14.025	14.21	2.331	4.5
SACROFANITE	62.5	44.734	12.241	13.2	15.454	3.112	0.59
TUGTUPITE	99.2	43.064	18.094	6.274	23.846	0.33	6.66

```
)Ident command"? unknown|d-values=3.55,6.15,2.51,2.03|save|match and
)6 minerals examined, 0 ignored, 5 not matched, 1 matched.
)Ident command"? tabulate unknown len 13 name opm d-values
```

Name	OPM	d-values				
unidentified sample		3.514 3.585	6.088 6.211	2.485 2.535	2.01 2.05	
TUGTUPITE	94.1	3.52	6.13	3.57	2.5	2.02

TABLE 7

)Ident command""? unknown|w O=41.44|w Na=18.83|w Al=5.78|w Si=24.61
)Unknown input""? w S=0.02|w Cl=7.41|d-values=3.55,6.15,2.51,2.03,2.325
)Unknown input""? save|identify
)3742 minerals examined, 0 ignored, top 20 identified.
)Ident command""? tabulate unknown name tm cm opm im d-values

Name	TM	CM	OPM	IM	d-values				
unidentified sample					3.514	6.088	2.485	2.01	2.302
					3.585	6.211	2.535	2.05	2.348
TUGTUPITE	97.0	99.0	94.1	100.0	3.52	6.13	3.57	2.5	2.02
SAPPHIRINE-1TC	70.1	71.4	100.0	88.9					
FERRO-ANTHOPHYLLITE	64.8	65.9	100.0	90.0					
PLAGIOCLASE	63.9	65.3	100.0	87.5					
CLINOHYPERSTHENE	63.4	64.6	100.0	88.9					
SCHULENBERGITE	62.8	81.6	30.9	100.0	7.186	3.581	3.209	2.7	2.527
SPODIOPHYLLITE	62.6	63.7	100.0	90.0					
ALKALI-FELDSPAR	60.5	61.8	100.0	87.5					
SODALITE	56.9	59.4	87.5	100.0	3.62	6.27	2.09	2.37	2.56
SERPENTINE	55.9	56.7	100.0	91.7					
FOWLERITE	55.3	56.1	100.0	91.7					
MCGILLITE	54.3	67.8	40.4	100.0	2.56	7.16	2.89	3.57	2.11
UM-7	53.7	54.4	100.0	91.7					
GIUSEPPETTITE	52.6	61.6	56.3	100.0	3.712	3.446	3.126	2.141	6.42
UM-9	52.2	53.0	100.0	91.7					
JUSITE	52.1	63.4	46.4	100.0	2.81	2.3	3.64	2.55	1.62
ISTISUITE	52.0	52.8	100.0	91.7					
NOSEAN	51.4	58.1	65.2	100.0	3.71	2.63	6.45	9.09	2.87
PSEUDOTHURINGITE	51.2	52.1	100.0	90.0					
ELISAVETINSKITE	51.1	68.4	23.9	100.0	4.75	2.35	1.87	1.44	9.68

NOTE: minerals for which there are no d-values tend to be favored because there cannot be a mismatch with the unknown d-values.

TABLE 8

)Ident command""? unknown|w H2O=1.91|w O=41.44|w Na=18.83
)Unknown input""? w Al=5.5-6.0|w Si=24-25|w S=0.02|w Cl=7.2-7.6
)Unknown input""? d-values=3.55, 6.15, 2.51, 2.03
)Unknown input""? n(omega)=1.5|n(epsilon)=1.5
)Unknown input""? symmetry=tetragonal, trigonal, hexagonal
)Unknown input""? colour(omega)=colourless
)Unknown input""? colour(epsilon)=colourless|save|match
)Element H with weight of 0.216% has been ignored (CUTOFF=1.0%).
)Element S with weight of 0.020% has been ignored (CUTOFF=1.0%).
)3742 minerals examined, 0 ignored, 3741 not matched, 1 matched.
)Ident command""? tabulate unknown name tm cm opm im -
)-""? n(omega) n(epsilon) symmetry

Name	TM	CM	OPM	IM	N(alpha)	N(beta)	Symmetry
unidentif					1.485	1.485	Multiple
ied sampl					1.515	1.515	
TUGTUPITE	94.7	98.4	94.1	88.9	1.496	1.502	Tetragonal

T A B L E 9

```

)Ident command"? unknown|w H2O=1.91|w O=41.44
)Unknown input"? w Na=18.83|w Al=5.78
)Unknown input"? w Si=24.61|w S=0.02|w C1=7.41
)Unknown input"? d-v=3.55,6.15,2.51,2.03,2.325
)Unknown input"? n(omega)=1.5|n(epsilon)=1.5
)Unknown input"? symmetry=tetragonal,trig,hex
)Unknown input"? colour(omega)=colourless
)Unknown input"? colour(epsilon)=colourless
)Unknown input"? save|identify
)3742 minerals examined, 0 ignored,
)top 20 identified.
)Ident command"? tab unknown name tm cm opm im

```

Name	TM	CM	OPM	IM
unidentified sample				
TUGTUPITE	94.5	98.2	94.1	88.9
FOWLERITE	64.4	68.2	100.0	66.7
FERRO-ANTHOPHYLLITE	50.2	59.4	70.0	66.7
FERRO-HORNBLENDE	49.5	58.2	70.0	70.6
GARNET	42.8	45.1	100.0	70.0
SPODIOPHYLLITE	40.5	47.8	70.0	68.7
ALKALI-FELDSPAR	39.7	42.8	100.0	57.1
MAGNESIO-ANTHOPHYLLITE	38.3	59.4	0.0	86.7
MAGNESIO-HORNBLENDE	37.7	58.2	0.0	88.2
CLINOFERROSILITE	36.8	57.0	0.0	86.7
CLINOHYPERSTHENE	36.8	57.0	0.0	86.7
UM-256	33.9	49.7	18.7	71.4
THORTVEITITE	32.6	48.9	0.0	100.0
PHOLIDOLITE	32.4	34.5	100.0	64.7
GIUSEPPEITITE	32.2	38.6	56.3	87.5
SACROFANITE	32.0	47.3	8.7	88.2
POLYLITHIONITE	31.8	45.9	12.3	90.9
FRANZINITE	31.8	37.0	63.1	88.9
WADSLEYITE	31.0	47.7	0.0	90.0
SODALITE	30.1	35.4	60.5	89.5

well as the TM index for each mineral listed. Such a tabulation could also be useful, for example, in suggesting to a user other properties that might be measured as a means of distinguishing among the various possibilities.

Another possible application of this tabulating facility is illustrated in Table 10, which lists the name, formula, density and PDF numbers of all known hydrated Be minerals. These are here arbitrarily defined as containing more than 0.5% Be and 0.1% H. Note that a few minerals that may contain minor Be and H, but that are not truly hydrated Be-minerals, appear in this list. It would be a simple next step to get the complete composition of any or all of the minerals shown in Table 10.

Because of the wide range of parameters that have been included, the data base offers the possibility of

examining the patterns of variation of any parameter with any other. A good example is provided by calculation of the Gladstone-Dale relationship (Mandarino 1979). In Figure 3, this relationship between mean index of refraction with density and composition has been plotted for all minerals in the data base that contain more than 10 wt.% oxygen. Table 11 shows the "compatibility index" for this large group of minerals, in terms of the percentage of the group showing superior, excellent, good, fair and poor compatibility, as defined by Mandarino (1979). However, no attempt has been made to apply the special constants recommended by Mandarino for inosilicates and nesosilicates; the same 'general' constants have been used throughout. Table 11 and Figure 3 are useful not only for demonstrating the wide applicability of this Gladstone-Dale relation-

TABLE 10

)Ident command""? unknown|w Be=0.5-100.0|w H=0.1-100.0|save|match
)3742 minerals examined, 0 ignored, 3693 not matched, 49 matched.
)Ident command""? tabulate unknown name w Be w H formula

Name	Be	H	Formula
unidentified sample	0.5 100.0	0.1 100.0	
ALLANITE	0.472	0.237	(Ce,Ca,Y)2(A1,Fe)3[Si04]30H
AMINOFFITE	2.234	0.722	Ca2(Be,A1)Si207OH:H2O
BAVENITE	2.202	0.307	Ca4Be2A12S19O26[OH]2
BAZZITE	4.81	0.291	Be3(Sc,A1)2S16O18
BEARSITE	6.035	3.245	Be2AsO4OH:4H2O
BEHOITE	20.945	4.685	Be[OH]2
BERBORITE	14.161	2.237	Be2BO3(OH,F):H2O
BERGSLAGITE	4.684	0.671	CaBeAsO4OH
BERTRANDITE	14.92	0.867	Be4S1207[OH]2
BERYL	4.513	0.189	Be3A12S16O18
BERYLLITE	14.413	2.484	Be3S104[OH]2:H2O
BERYLLIUM-MARGARITE	0.822	0.5	(Ca,Mg,Fe2+,Ba)(Li,Na,K)O.25(A1,Fe3+)2(... *
BITYITE	1.792	0.727	CaLiA12A1BeS12010[OH]2
BOWLEYITE	2.765	0.645	CaLiA12A1BeS12010[OH]2
CHIAVENNITE	3.351	1.264	CaMnBe2S15O13[OH]2:2H2O
EPIDIDYMITE	3.995	0.443	NaBeS1307OH
EUCLASE	6.781	0.673	BeA1S104OH
EUDIDYMITE	3.874	0.439	NaBeS1307OH
FAHEYITE	2.753	1.754	(Mn,Mg)Fe3+2Be2[PO4]4:6H2O
FRANSOLETITE	3.351	1.6	H2Ca3Be2[PO4]4:4H2O
GLUCINE	10.497	1.533	CaBe4[PO4]2[OH]4:0.5H2O
GUGIAITE	3.311	0.094	Ca2BeS1207
HAMBERGITE	19.25	1.153	Be2BO3OH
HARSTIGITE	7.11	0.287	Ca6(Mn,Mg)Be4S16(O,OH)24
HELBERTRANDITE	12.309	2.662	(Be,Ca)4(Si,A1)207[OH]2:3H2O
HERDERITE	5.652	0.531	CaBePO4F
HINGGANITE	3.783	0.439	(Y,Yb)BeS104OH
HINGGANITE-(YB)	3.879	0.425	(Yb,Y)BeS104OH
HYDROXYL-HERDERITE	5.782	0.654	CaBePO4OH
IDOCRASE	0.262	0.209	Ca10Mg2A14[Si04]5[Si207]2[OH]4
JEFFREYITE	2.919	0.201	(Ca,Na)2(Be,A1)Si2(O,OH)7
JOESMITHITE	1.718	0.727	(Ca,Pb)3(Mg,Fe2+,Fe3+)5S16Be2O22[OH]2
KARPINSKYITE	0.93	0.839	Na2(Be,Zn,Mg)A12S16O16[OH]2
LEIFITE	1.369	0.336	Na2(Si,A1,Be)7(O,OH,F)14
LEUCOPHANE	3.956	0.107	(Na,Ca)2BeS12(O,OH,F)7
LOVDARITE	2.486	1.375	(Na,K,Ca)4(Be,A1)2S16O16:4H2O
MELIPHANITE	3.764	0.034	(Ca,Na)2Be(Si,A1)2(O,OH,F)7
MILARITE	1.891	0.179	K2Ca4A12Be4S124O6O:H2O
MORAESITE	9.109	4.454	Be2PO4OH:4H2O
RHODIZITE	4.373	0.059	CsA14Be4B11O25[OH]4
ROSCHERITE	4.634	1.341	Ca(Mn,Fe2+)2Be3[PO4]3[OH]3
SEMOVITE	2.964	0.201	(Ca,Ce,La,Na)10-12(Fe,Mn)(Si,Be)2O(O,OH,F)48
SORENSENITE	2.783	0.573	Na4SnBe2S16O16[OH]4
SPHEROBERTRANDITE	16.286	1.309	Be5(Si,A1,Fe3+)207[OH]4
TIPTOPITE	5.441	0.38	(Li,K,Na,Ca)8Be6[PO4]6[OH]4
TUGTUPITE	1.928	0.337	Na4BeA1S14O12C1
URALOLITE	6.717	2.455	CaBe3[PO4]2[OH]2:4H2O
VAYRYNENITE	4.582	0.581	BeMnPO4(OH,F)
WOROBYEVITE	4.036	0.246	Be3A12S16O18

* Formula truncated. NOTE: Concentrations shown for Be and H are average values.

ship but also for highlighting inconsistencies. Thus a first version of Figure 3 revealed several grossly discrepant points that were quickly traced to entry errors in the data base. Less extreme discrepancies may also arise from errors in one or more of the parameters used in calculating the relationship, i.e.,

indices of refraction, density and composition. Other errors may remain in the Gladstone-Dale constants used, and it may be necessary to use constants 'tuned' to particular types or groups of minerals if a tighter fit is to be achieved.

Several systems now exist for automated modal

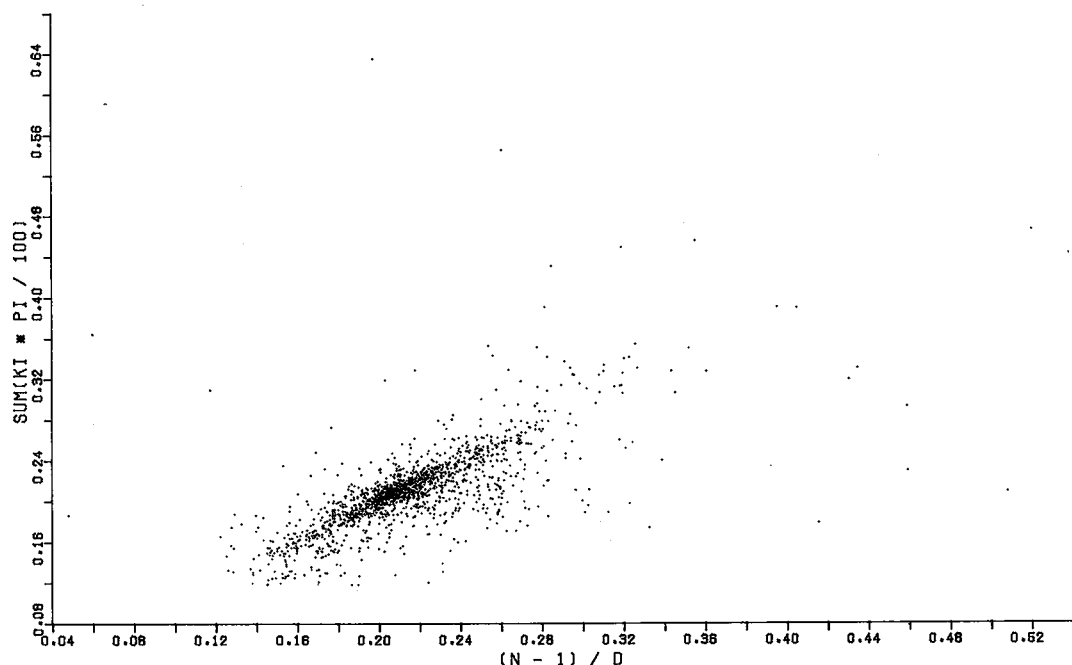


FIG. 3. Gladstone-Dale relationship between molar refractivity calculated from physical measurements $[(N - 1)/D]$ and from chemical data $[\text{Sum} (KI * PI / 100)]$.

T A B L E 11

GLADSTONE DALE RELATIONSHIP:
COMPATIBILITY INDICES

SUPERIOR	505 ANALYSES	31%
EXCELLENT	355 ANALYSES	22%
GOOD	176 ANALYSES	11%
FAIR	128 ANALYSES	8%
POOR	457 ANALYSES	28%

all of the minerals present or, alternatively, simply identifying those not previously noted by the user. Once the identity of a mineral with a given set of X-ray-emission characteristics has been recognized by MINIDENT, all points having these characteristics might be automatically allocated to that mineral without further intervention by MINIDENT. Here we see the possibility of developing one of the so-called "expert systems". Such an application has been neither tried nor tested to date.

CONCLUSIONS

analysis by electron microprobe, some being available commercially for use with energy-dispersion spectrometers. At present the successful application of such software is dependent upon a proper recognition of the minerals present in a rock and, with the aid of the analytical system, definition of these in terms of their X-ray-emission characteristics. Such systems work well for common minerals present in major amounts. They do not function so well, however, for minor modal constituents, opaque phases, or uncommon minerals, all of which tend to be overlooked and hence end up in an undifferentiated "other minerals and mixtures" group. One can envisage MINIDENT being of considerable use in such applications, either as a means of recognizing

MINIDENT is now a working and useful package, although it is certainly far from fully developed or complete. Significant gaps remain in the data for particular parameters (*e.g.*, co-ordination number of cations), and fields for many other properties might be added. Thus no information has been included so far on thermodynamic constants, electrical and magnetic properties, nor have any D.T.A. data been included. Data missing from existing fields will be added as soon as practicable, and the data base will be updated periodically as new minerals are described and when previously described but unnamed minerals are given an IMA-approved name. With so many data entered into the existing data base, it is inevitable that errors will have been inadvertently

introduced. These will be corrected as soon as they come to light.

Future developments may include the use of new fields if it appears that this would significantly improve the usefulness of the program. However, the mineral, sample and general data on which the compiled data are based already occupy 12 Mbytes. It is, therefore, stored on tape between use and updating. The compiled data base presently occupies 4 Mbytes. Obviously there are practical limits to the extent to which these data bases can be expanded, particularly the compiled data base, which must be accessible from disk before any identification can be performed. At the time of writing MINIDENT is being run on an AMDAHL 580/FF mainframe computer, and typically each MATCH procedure takes about 0.05 seconds CPU time to run. The IDENTIFY procedure is somewhat more expensive, running in about 3 seconds if the entire data base is being considered. Efforts will be made to reduce running times (and hence costs) in future versions. Furthermore, attempts may be made to produce a microcomputer version. This would certainly require the availability of a high-capacity rapid-access storage facility such as a hard disk. The MINIDENT data base is not for sale. However, it can be accessed at the University of Alberta Computer Centre through DATAPAC or other similar data-communications networks. Potential users should contact the first author for further information concerning procedures for registering with the Computer Centre as a user.

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At various times over the last several years the following people have contributed substantially to this project by entering information into the data base. Their meticulous care while carrying out a task that must often have been wearisome has been essential to the success of the project: Louise de St. Jorre, Jay Guidos, Chuck Mah, Heideh Omoumi, Morris Maccagno, Edith Hutcheson, Robert Pinckston, Jan Schutz and Keith Tymofichuk. Mr. Desmond Wynne has provided invaluable advice on computing matters throughout this project. We are also grateful to Dr. J.A. Mandarino for helpful discussions and to Dr. J.A. Jambor for critically reading the manuscript. Part of the work has been supported financially by NSERC grant number A4254 to the first author.

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