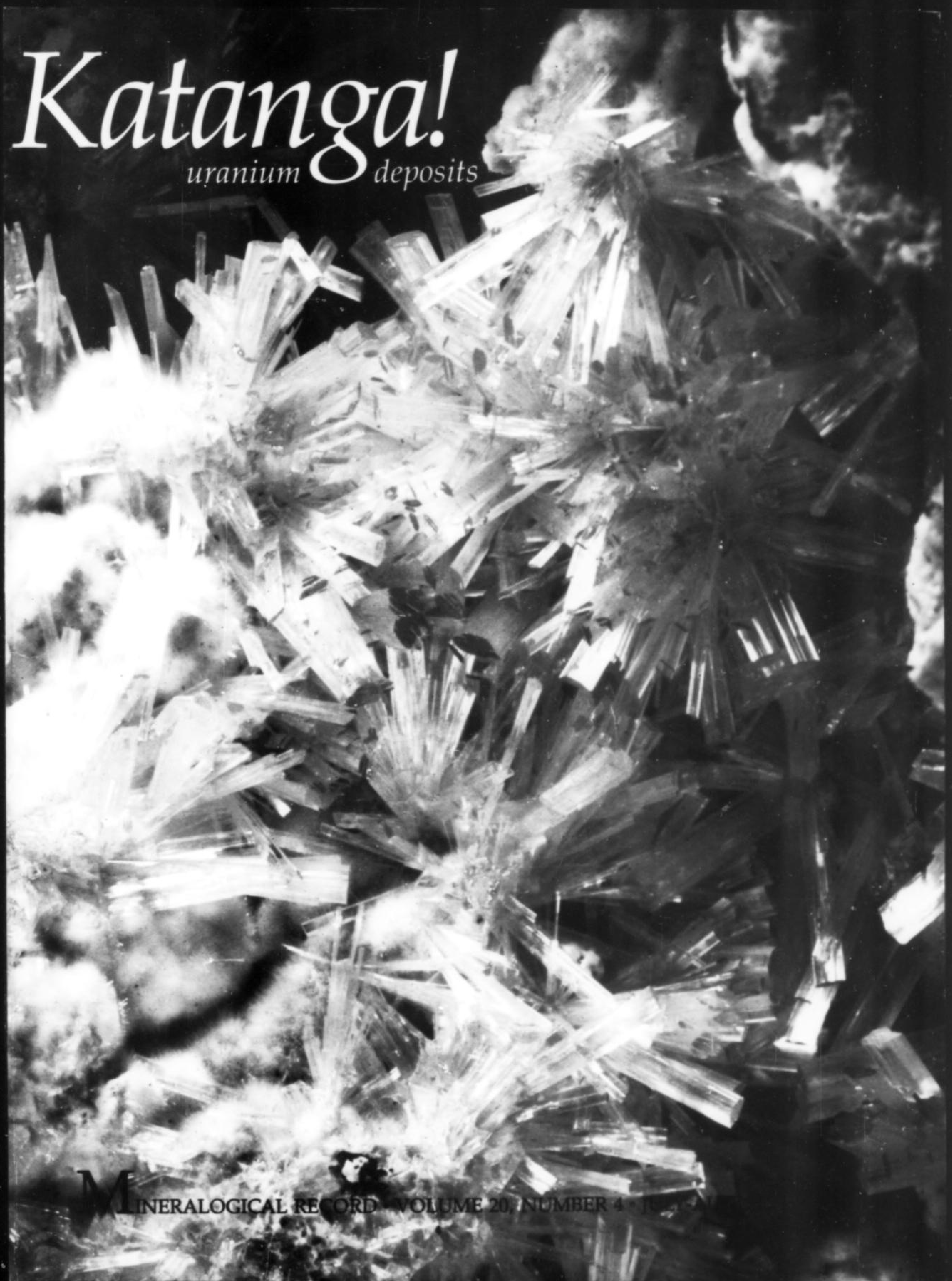
Katanga!

uranium deposits



MINERALOGICAL RECORD • VOLUME 20, NUMBER 4 • JU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*Continued on p. 319

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July–August 1989
Volume Twenty, Number Four

Articles

Departments

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RANDOLPH S. ROTHSCHILD

COVER: BECQUERELITE crystals to 5 mm, with uranophane, from the Shinkolobwe mine, Shaba (formerly Katanga), Zaire. Sorbonne collection, Paris; photo by Nelly Bariand. See the article on the uranium deposits of Shaba, beginning on page 265 of this issue.

notes from the EDITOR

THE RECORD LIBRARY

From time to time mention is made of the Record Library, either as the source of published information and illustrations, or in the context of donations needed. Indeed, many of our subscribers have made very useful donations, particularly in helping us complete our sets of various periodicals, and also with gifts of books as well as cash donations for book purchases. It occurred to us that readers might like to have a progress report on how the library is coming along, and perhaps also some general background.

Since the earliest days of the *Mineralogical Record,* books on minerals and mineral deposits have been steadily accumulating in the editorial office. Arthur Montgomery, whose generous financial support helped to establish the magazine during its first three years, saw the need for reference works and donated many useful volumes to then-editor John White. Each year since then, additional volumes have been added as donations or purchased with donated funds, and still others have been received as review copies from publishers.

The growth of the Record Library was modest at first, but has increased in recent years. This is the result of greatly increased donations. Three years ago the Thomas Buza Library (about 1000 volumes valued at $15,000) was received as a gift, and in 1988 a total of $22,000 in grants was received specifically for the library. A donation of $3800 was received not long ago for the purchase of a set of Sowerby's *British Mineralogy,* which includes 550 hand-colored copper-plate engravings of British mineral specimens. Many other smaller donations have been received as well. (Subscription funds are not used for library purchases, and so the cost of a subscription to the *Mineralogical Record* has remained unaffected.)

Currently the library consists of about 2500 volumes. Less than a hundred of these might be considered collectibly antiquarian. The rest are recent works of many different kinds which may not be especially valuable in terms of dollars but which can be indispensible for the purposes of mineralogical literature research.

It is remarkable and lamentable how poorly stocked even the largest of university libraries can be with regard to mineralogical materials. Books of historical interest, and books dealing with the mineralogy of various countries, states and other local geographical divisions are found on public shelves rather rarely and never in a really comprehensive, accessible collection. This is why it became useful for the *Mineralogical Record* to begin developing its own "special collection." We are, after all, in the information business, and a library is concentrated information for us to draw on. Authors and the editorial staff routinely need access to books and publications which would otherwise be very difficult to find. The result is an improved, enhanced and more authoritative magazine.

On what basis do we select books for the library? Solely on the basis of the information contained. Where inexpensive reprints are available we prefer those to more costly originals. However, in the case of colored illustrations for possible reproduction in the magazine we must have originals. (This more or less holds true for crystal drawings, specimen sketches and other black and white line figures which can also suffer in reproduction.) Where English translations are available we naturally give priority over earlier or later editions in other languages; otherwise, we take materials in whatever languages are available.

As to the occasional older works, we are decidedly not collector-oriented. For example, we much prefer sturdily rebound copies or broken bindings (at appropriate discounts) which we can have rebound, rather than original but brittle bindings unable to stand up to serious use. Nor is there any practical value to us in uncut copies, unopened copies, signed or inscribed copies, original paper wraps on never-bound copies, and so on. These are fine for the bibliophile, but not for the researcher.

As to the actual content of the library, a number of subdivisions or sub-collections are currently being assembled which have proven to be the most useful to *Mineralogical Record* editors and authors. The first includes the standard editing tools: atlases, dictionaries, glossaries, technical encyclopedias, style manuals, graphics and typography source books, etc. The second includes reference works to the literature, such as indexes and bibliographies of all sorts, and catalogs of other mineralogical libraries. Third are the periodicals, nearly 40 different journals and magazines in all. Through these we maintain access to the ongoing technical literature and also to the collector literature which is so often missing in public and institution libraries. Beyond that we have a selection of recent (and very difficult to find) English translations of ancient and medieval works on mineralogy, some nineteenth-century mineralogies, a good collection of works on mining history and economic geology, plus a range of other books on such topics as gemology, crystallography, geochemistry, museums, and the history of science.

A picture archive is also a part of the library; it contains a wide range of materials, including early mining photos, engravings of mining scenes and mineral specimens, and a large collection of mineral photographs donated by various photographers, not to mention hundreds of candid or portrait photos of mineralogists, dealers, curators and prominent collectors.

Where do we go from here? It has been estimated that roughly 8,000 books have been published on mineralogy since ancient times, and many more on subjects such as regional geology/mineralogy and mining history. A very rough guess would therefore be that about 15,000 titles comprise the total sum of the literature of mineralogy and closely related fields. No institution in the world has come close to actually completing such a collection. Nevertheless, what we have has already proven extremely useful on a daily basis, and can only grow more so with future additions.

The Record Library is not a lending library; authors and associate editors obtain access through the editor, and only rarely make personal visits. Editorial assistance in utilizing library materials, for the present at least, comes strictly in the context of help with articles in preparation for publication in the *Mineralogical Record,* usually after a first draft has been completed, but sometimes before. Because the Mineralogical Record Inc. has no formal office building, and lacks a full-time receptionist or library assistant, the Record Library is not now as readily accessible to all writers, researchers and students as we would like it to be. However, we expect that the situation will eventually improve, allowing the library to be of maximum accessibility and benefit to the science in general as well as to the *Mineralogical Record* magazine specifically.

From the authors and editors, our thanks to the many generous people who have contributed to make the Record Library what it is. Additional donations are always welcome, and are tax-deductible.

Romé Delisle ✝ *and his Bibliography*

Wendell E. Wilson
4631 Paseo Tubutama
Tucson, Arizona 85715

Jean-Baptiste Romé Delisle (or De L'Isle) was born in Gray, France, in 1736, and died in Paris in 1790. He and the Abbé René Just Haüy are today acknowledged as the founders of modern crystallography.

Romé Delisle, the son of a cavalry lieutenant, studied humanities at the College of Saint Barbe in Paris. Following his graduation he joined the military in 1756 and served as a secretary in the Royal Corps of Artillery and Engineering in the French Indies. When the enclave at Pondicherry fell to the English in 1761 he was taken captive and held as a prisoner of war in China for three years, before being allowed to return to France.

Back in Paris once again, he met the mineralogist B. G. Sage and attended his lectures in chemistry. In 1767 Romé Delisle was hired, on Sage's recommendation, to prepare a catalog of the specimens in the natural history cabinet of Pedro Francisco Davila, a Peruvian nobleman visiting in France and wishing to sell his collection. The work ran to three volumes, in which Romé Delisle stressed the importance of crystalline form in his description.

Romé Delisle apparently enjoyed this close study of diverse specimens, because he continued to earn money preparing similar catalogs for at least fourteen other mineral collections.

In 1772 he published his first important work, *Essai de Cristallographie* (1 volume, 427 pages plus ten plates of crystal drawings and two large fold-out tables), in which he identifies 110 crystal forms. This was a major expansion upon the work of Linnaeus, who listed only 40. Romé Delisle described each of the forms carefully and the minerals that exhibit them, subdividing the various minerals into salts, stones, pyrites and metallics. Like Linnaeus, he believed that external crystal form should be the chief method of classifying minerals.

Romé Delisle and Linnaeus both felt that the crystal forms of minerals could be affected by a contamination with salts, and so they listed primitive forms as well as more complex modifications supposedly induced by salts for each species.

Nicolaus Steno had discovered the constancy of interfacial angles on quartz crystals over a century earlier; although Romé Delisle had read the work, he nevertheless did not see its significance and did not utilize precise angular measurements in his crystal descriptions.

Romé Delisle's more important work, his four-volume *Cristallographie* (1783), was advertised as a second edition of his *Essai*, but in fact it qualifies as an almost entirely new work. Again following Linnaeus and Domenico Guglielmini, he based his classification on a comparison with simple geometric forms such as the cube, tetrahedron, octahedron, dodecahedron, etc. But there was a critical improvement over the *Essai*. While making terra cotta crystal models, Romé Delisle's assistant Arnould Carangeot rediscovered the constancy of interfacial angles which Romé Delisle had overlooked in Steno's work. Carangeot invented the first contact goniometer in order to pursue such measurements on all of the minerals Romé Delisle discussed, and provided data accurate to within about half a degree.

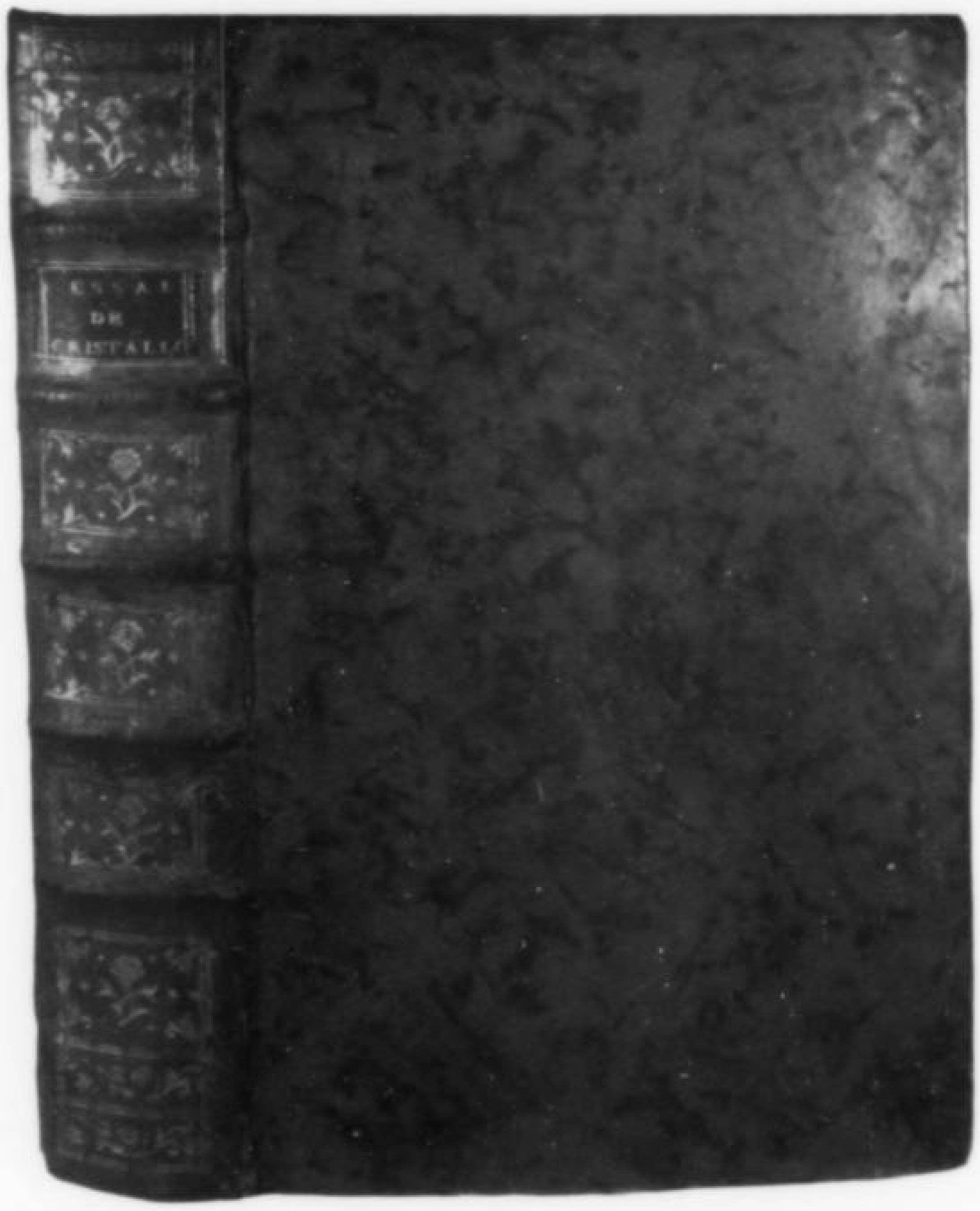
The fundamental law of the constancy of interfacial angles for any given species, no matter how apparently distorted the individual crystals might appear, told Romé Delisle that each species must be characterized by specific idealized forms with constant angles. Romé Delisle believed the chief task of crystallography was to discover how the secondary crystal forms, modifications and truncations could be derived from the more basic forms. He found this mystery so impenetrable and disturbing that he eventually concluded the more complex forms to be crystal defects, even though he steadfastly maintained that their interfacial angles were equally as consistent as those of the simple forms.

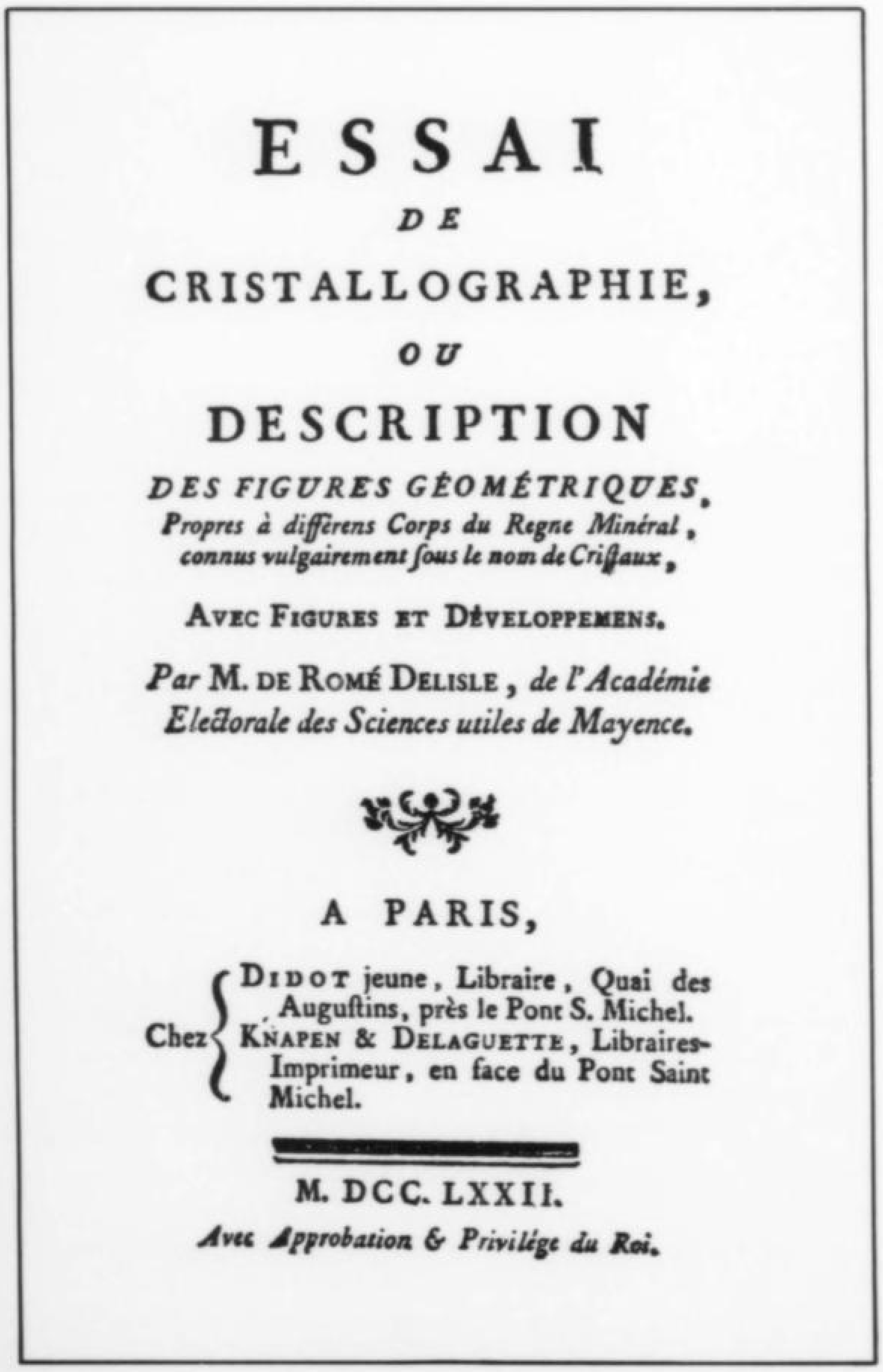
Romé Delisle correctly concluded that even though some different species might share identical crystal forms, they could usually be distinguished by other properties such as density and hardness. Furthermore, he discussed what he called the "integrant molecule" for each species, which he believed must be equal in shape to the mineral's primitive (simplest) crystal form, must be relatively constant and characteristic for each species, and must contain the same constituents in the same proportions. This is almost identical to the modern concept of the unit cell.

While compiling his *Cristallographie,* Romé Delisle became convinced that Linnaeus' theory about salt contamination influencing crystal forms must be wrong, since each species must have a characteristic set of forms and a relatively constant composition. But Romé Delisle had only a vague appreciation for symmetry, and did not recognize, for example, that the cube and octahedron reflected identical internal symmetry.

Romé Delisle's relationship with Haüy was strained, at best, and he was sharply critical of the speculative nature of the theories Haüy was developing. Romé Delisle adhered to unwavering empiricism, and felt that studies of crystal morphology were as yet too poorly understood to allow further conclusions on the internal arrangement of atoms which could not be directly observed. He declined to substitute "the dreams of our imagination for the majestic silence of nature." Haüy, in turn, chose to ignore Romé Delisle's work as completely as possible.

For Romé Delisle's own attempts at speculation upon internal structure, he might indeed have been better off avoiding the subject. He hypothesized, for example, that





ESSAI

DE

CRISTALLOGRAPHIE,

OU

DESCRIPTION

DES FIGURES GÉOMÉTRIQUES,
Propres à differens Corps du Regne Minéral,
connus vulgairement ſous le nom de Criſtaux,

AVEC FIGURES ET DÉVELOPPEMENS.

Par M. DE ROMÉ DELISLE, *de l'Académie*
Electorale des Sciences utiles de Mayence.

A PARIS,

Chez { DIDOT jeune, Libraire, Quai des Auguſtins, près le Pont S. Michel.
KNAPEN & DELAGUETTE, Libraires-Imprimeur, en face du Pont Saint Michel.

M. DCC. LXXII.

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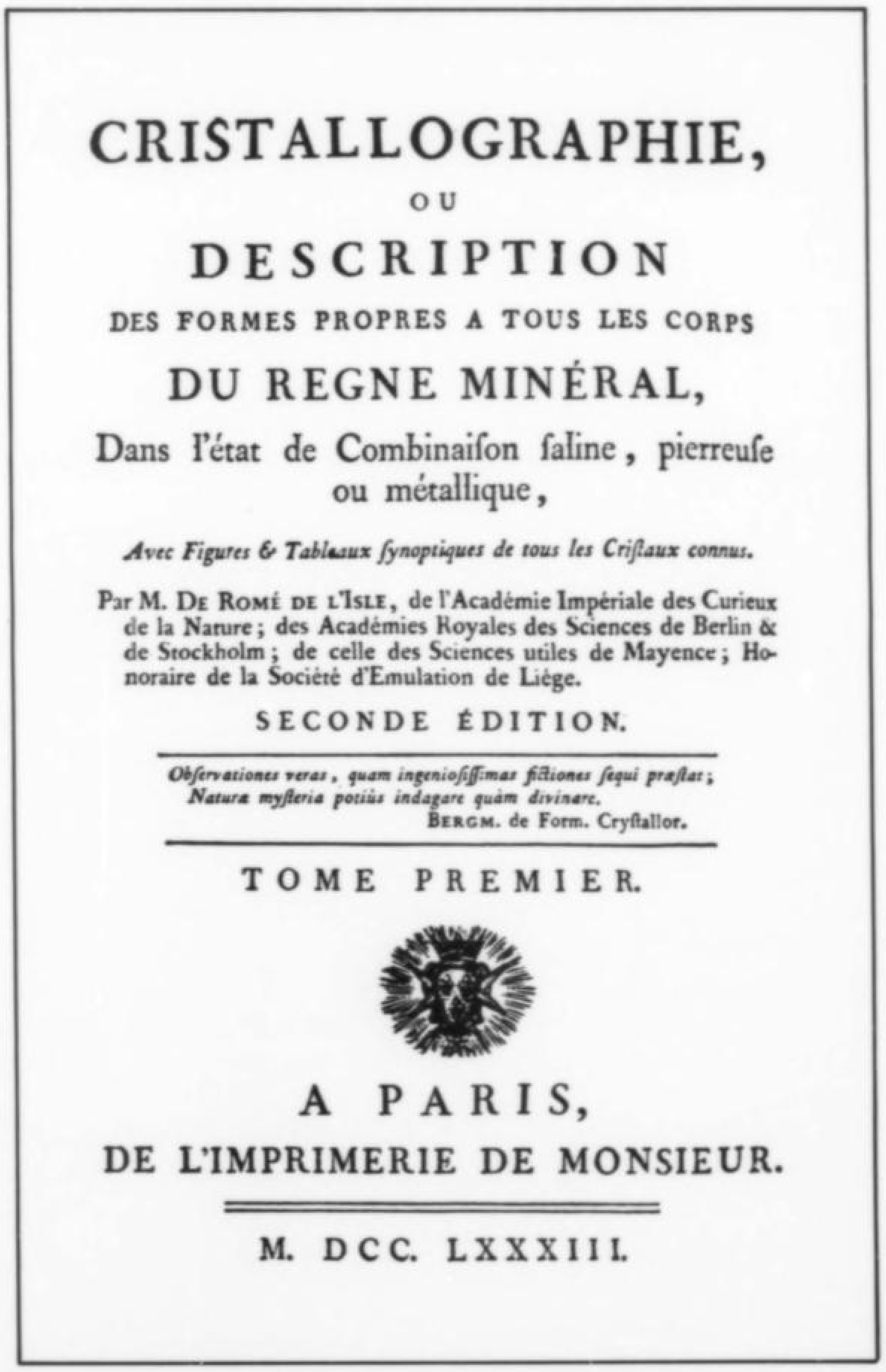

CRISTALLOGRAPHIE,

OU

DESCRIPTION

DES FORMES PROPRES A TOUS LES CORPS

DU REGNE MINÉRAL,

Dans l'état de Combinaiſon ſaline, pierreuſe
ou métallique,

Avec Figures & Tableaux ſynoptiques de tous les Criſtaux connus.

Par M. DE ROMÉ DE L'ISLE, de l'Académie Impériale des Curieux de la Nature; des Académies Royales des Sciences de Berlin & de Stockholm; de celle des Sciences utiles de Mayence; Honoraire de la Société d'Emulation de Liége.

SECONDE ÉDITION.

Obſervationes veras, quam ingenioſiſſimas fictiones ſequi præſtat;
Naturæ myſteria potiùs indagare quàm divinare.
BERGM. de Form. Cryſtallor.

TOME PREMIER.

A PARIS,

DE L'IMPRIMERIE DE MONSIEUR.

M. DCC. LXXXIII.

the "integrant molecule" in a particular species must be variable in shape according to the external crystal habit.

In 1785 Romé Delisle was granted a pension from the public treasury, and in 1789 a further stipend from the personal treasury of the King, Louis XVI. He died in 1790.

Romé Delisle's chief contribution to science was his formulation of the constancy of interfacial angles as a general law for all minerals, though several early investigators since Steno's time had made incidental comments about such constancy for one or two substances. This helped to establish mineralogy on a firm crystallographic basis.

Romé Delisle also encouraged his friend, Fabien Gautier d'Agoty, to publish an extraordinary set of colored engravings of mineral specimens in his *Natural History* (1781); Romé Delisle wrote the explanatory captions for all the engravings.

The above information was taken largely from the *Dictionary of Scientific Biography* and from J. G. Burke's *Origins of the Science of Crystals* (Berkeley, 1966).

PRICE NOTES

On today's antiquarian book market, Romé Delisle's one-volume *Essai de Cristallographie* (1772) might bring $800–900. His second edition, *Cristallographie* (1783), three volumes and an atlas of crystal drawings, might be worth about $1500–$2000 in fine, complete condition and in original contemporary bindings. Gautier d'Agoty's volume of colored mineral illustrations can sell for as much as $20,000.

BIBLIOGRAPHY

Unlike many authors of his day, Romé Delisle published a thorough bibliography in his *Essai* (12 pages) and in his *Cristallographie* (46 pages). Listed below are some of the more interesting or familiar entries from the latter work, including his list of the collection catalogs he prepared for various collectors. He also mentions studying the collections of Messrs. Beost, Bertin, Besson, Bolza, Brakenhof, Cramayel, d'Angiviller, Galois, Grollier, Joubert, Leschevin, Macquart, Morosini, Nolin, Pabst de Oheim, Richter, Sayve, Septala, Tidstrom, Tollot, and the Prince of Lichtenstein.

The following bibliography is in Romé Delisle's original format, with his occasional annotations, except for conversions to the modern form of the letters "s" and "ae."

◆

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—Introduction à la Minéralogie, &c. trad. par le même. *Paris,* 1756, 2 vol. *in*-12°.

—Ejusd. *Henckelii de topazio verâ Saxonum, orientali non inferiore.* Ext. in act. phys. Med. IV, Obs. 82, p. 317 & seqq.

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(Tout ce qui est relatif à l'Histoire naturelle des pierres, dans le supplément de l'Encyclopédie de chambers, est tiré de cet Ouvrage).

—*Fossils arranged, according to their obvious characters, &c. London,* 1771, *in*-8°. (Les caractères distinctifs des substances minérales y sont distribués en huit colonnes, savoir; 1°. la forme; 2°. la dureté; 3°. la pesanteur; 4°. la surface; 5°. la coleur; 6°. la qualité; 7°. le lieu d'origine; 8°. enfin l'usage & la synonimie.)

I. - J.

JEFFRIES (David). Traité des diamans & des perles, trad. de l'angl. par M. Chappotin-Saint-Laurent. *Paris,* 1753, *in*-8°.

IMPERATI (Ferrante). *Historia naturale, nella quale ordinatamente si tratta di diversi condition di minere, pietre pretiose, &c. Venezia,* 1672, *in-fol. fig.* (Cet Auteur a donné plusieurs figures de cristaux de roche, qui ont été copiées par Sibbald, Mercati, &c.

JUSTI (G. H. Gotlobs von-). Minéralogie en allem. sous ce titre: *Grundriss des gesamten mineral reiches, &c. &c. Gotting.* 1757, *in*-8°.

K.

KENTMANN (J.). *Nomenclatura rerum fossilium quae in Misniâ praecipuè & aliis quoque regionibus inveniuntur. Extatinter Conradi Gesnero de omni fossilium genere libros.* Tiguri, 1565, *in*-8°.

KIRCHER (Athan.). *Mundus subterraneas*. Amst. 1678, 2 vol. *in-fol.* fig. (*In tom. II, lib. VII, cap. 8, de crystallis agitur*).

KOENIGH (Emman.). *Regnum minerale*. Basileae Rauracor, 1686, *in*-4°. *Idem*, Basileae, 1703, *in*-4°.

KUNDMANN (J. Christian). *Rariora Naturae & Artis* Uratislaviae, *in-fol.* (Cet Auteur a décrit quelques diamans à la page 190. Il parle aussi de la pierre quarrée chinoise, ou pyrite cubique, à la page 178).

L.

LAET (J. de). *De gemmis & lapidibus, libri duo*. Lugd. Batav. 1647, *in*-8° cum figuris. (Cet Auteur a décrit exactement la forme cristalline de plusieurs pierres précieuses)

LANA (Franç.). *Reflexions made upon an observation of Signor M. Antonio Castagna, concerning the formation of cristals.* Dans les Transact. philos. angl. vol. 7, n° 83, & dans la Collect. acad. part. étrang. tome 4, p. 25.

LANG (Ch. Nic.). *Historia lapidum figuratorum Helvetiae ejusque viciniae*. Venetiis, 1708, *in*-4°, *fig*.

—Ejusd. *de origine lapidum figuratorum*. Lucernae, 1709, *in*-4°, *fig*.

LINNÉ (Charl. Von-). *Systema Naturae*. Lugd. Batav. 1756, *in*-8° (*editio nona*). Idem, *Holmiae*, 1766, 3 vol. *in*-8° (*editio duodecima*). (Le troisième tome, qui comprend le regne minéral, parut en 1768. Les cristaux y font très-bien décrits & représentés au nombre de 40 dans une seule planche avec deux planches de développemens de ces mêmes cristaux.

M.

MERCATI (Mich.). *Metallotheca Vaticana, cum appendice & uotis Mariae Lancisi*. Romae, 1717 & 1719, *in-fol. fig.* (L'appendice contient quelques planches de cristaux).

MONNET (M.). Nouveau Systême de Minéralogie. *Paris*, 1779, *in*-12°. (L'Auteur, Inspecteur géneral des mines, & qui connoît sans doute mieux que personne la *physionomie & l'allure* des minéraux.

P.

PALLAS (M.). Voyage en Sibérie (en allem.). *Pétersbourg*, 1773, 3 vol. *in*-4°, *fig*. (L'Auteur y a représenté les cristaux de la mine de plomb rouge, de la pyrite en cubes striés, &c.). Une partie de ces Voyages a été traduite dans l'Histoire des Découvertes faites par divers savans Voyageurs dans plusieurs contrées de la Russie & de la Perse, relativement à l'Histoire civile & naturelle, &c. *Berue & la Haye*, 1779 & 1781, 2 vol. *in*-4°.

PRYCE (Will.). *Mineralogia Cornubiensis*. Lond. 1778, *in*-fol. *Anglic'age*. Cité II, 304.

R.

ROMÉ DE L'ISLE (J. B. L. de). Essai de Cristallographie, ou Description des figures géométriques propres à différens corps du règne minéral, connus vulgairement sous le nom de cristaux. *Paris*, 1772, *in*-4°, avec huit planches de cristaux, & deux de développemens. C'est le première édition de cet ouvrage.

—Description méthodique d'une collection de minéraux du cabinet de M. D. R. D. L. *Paris* 1773, *in*-8°. (On y trouve la description de plusieurs cristaux métalliques.)

NOTICE des principaux Catalogues d'Histoire naturelle que j'ai rédigés, depuis 1767 jusqu'à présent.

1°. Toute la partie qui concerne l'histoire naturelle, dans le Catalogue de M. Davila. Voyez son article, ci-dessus, p. 578.

2°. Catalogue raisonné d'une collection choisie de minéraux, cristallisations, &c. (pour la première vente publique de Jacob Forster). *Paris*, 1769, *in*-8°.

3°. Catalogue raisonné d'une collection choisie de minéraux, cristallisations, &c. (pour la seconde vente publique de Jacob Forster). *Paris*, 1772, *in*-8°.

4°. Catalogue raisonné des curiosités naturelles qui composent le cabinet de M. de *** (Varennes de Béost). *Paris*, 1774, *in*-8°.

5°. Catalogue raisonné d'une cabinet d'histoire naturelle, composé de minéraux de plus beau choix. *Paris*, 1777, *in*-8°.

6°. Catalogue raisonné d'une collection de minéraux, cristallisations, fossiles, pétrifications, &c. du cabinet de M. D. ***. 1778, *in*-8°.

7°. Catalogue raisonné d'une collection de minéraux, cristallisations, &c. (pour la troisième vente publique de Jacob Forster). *Paris*, 1780, *in*-8°.

8°. Catalogue raisonné des minéraux, cristallisations, &c. qui composent le cabinet de M. Galois. *Paris*, 1780, *in*-8°.

9°. Catalogue raisonné des minéraux, cristallisations, &c. qui composient le cabinet de feu M. de l'Isle. *Paris*, 1780, *in*-8°.

10°. Description du cabinet d'histoire naturelle de M. le marquis de G***. *Paris*, 1780, *in*-8°.

11°. Catalogue raisonné d'une collection choisie de minéraux, cristallisations, &c. (pour la quatrième vente publique de Jacob Forster). *Paris*, 1783, *in*-8°.

12°. Catalogue raisonné du cabinet de M. le comte d'Angiviller, *mss.* Ce *Manuscrit* est actuellement entre les mains de M. le comte de Buffon, qui a fait l'acquisition de ce cabinet pour le réunir à celui du Roi.

13°. Catalogue raisonné du cabinet de M. de Lassone, de l'Académie Royale des Sciences, & premiere Médecin de la Reine, à Versailles. *Manuscr.*

14°. Description du cabinet de M. Leschevin, premier Commis de la Maison du Roi, à Versailles. *Manusc.* Ce manuscrit, & le précédent, sont entre les mains des possesseurs de ces cabinets.

S.

STENON (Nic.). *Prodromus dissertationis de solido intrà solidum naturaliter contento*. Florentiae, 1669, *in*-4°. (La traduction françoise de cet Ouvrage se trouve par extrait dans la *Collect. acad. de Dijon*, tom. 4, part. étrang. p. 377 & *suiv.*).

T.

THÉOPHRASTE. Son Traité des pierres se trouve en grec & en latin à la suite du Traité de Boece de Boot, *de gemmis & lapidibus*, 1647, *in*-8°. La traduction françoise, avec les notes de Docteur Hill sur cet Auteur, a été imprimée à Paris en 1754, *in*-12°.

V.

VOGEL (D. R. A.). *Mineral system*. Leipsig. 1762, *in*-8°.

W.

WOLTERSDORFF (J. Luc). *Systema minerale*. Berolini, 1748 & 1755, *in*-4° *oblongo*.

WOODWARD (John). *A Catalogue of the english native fossils*. London 1728, *in*-8°.

Photo by Earl Lewis, Hollywood

famous mineral localities:

THE URANIUM DEPOSITS OF THE SHABA REGION, ZAIRE

Gilbert Gauthier
7 Avenue Alexandre III
78600 Maisons-Laffitte
France

Armand François
26 Avenue du Hoef
B 1180 Bruxelles
Belgium

M. Deliens
Section of Mineralogy and Petrography
Institut royal des Sciences naturelles
Brussels, Belgium

P. Piret
Crystallography Laboratory
University of Louvain-la-Neuve
Belgium

Since the days of Stanley and Livingstone, Shaba (Katanga) has been known as one of the world's great mineralized areas. Locality names such as Musonoi and Shinkolobwe are today famous for some of the finest and rarest crystallized uranium minerals ever found anywhere.

INTRODUCTION

Located in central Africa to the north of the South African craton, the so-called South Equatorial polymetallic ore province straddles Zaire and Zambia. It is a gigantic accumulation of stratified upper Precambrian rocks containing copper and cobalt ores, with other metals associated locally, particularly nickel, vanadium, uranium, gold, silver and the platinum group metals. This province, forming a belt more than 500 km long, consists of a northern and a southern zone of similar ages but very different characteristics.

The northern zone, located entirely within Shaba province, Zaire, is shaped like a crescent about 300 km in length and nearly 50 km in width. It extends from the town of Kolwezi in the west to the city of Lubumbashi in the east. We will refer to this zone as the Shaba Crescent. There is no continuity among sedimentary rocks within the zone; the stratigraphy has been severely disrupted by tectonic events. It is within the Shaba Crescent that the important uranium-bearing minerals have been found. The southern zone, located mainly in Zambia and known as the Zambian Copper Belt, is in rocks that have been much less disrupted.

To avoid confusion, it should be noted that the lead-zinc deposits of southern Shaba lie outside the Shaba Crescent, as does the large Kipushi mine, which has yielded lead, zinc, silver, copper, cadmium, germanium and arsenic. The Kipushi deposit is a vein occurrence similar to the one at Tsumeb, Namibia. The same is also true of the tin and bismuth deposits in the northern part of southern Shaba, which lie entirely in granitic and metamorphic rocks.

The name of the geopolitical province was changed from Katanga to Shaba about 20 years ago, after the Belgian Congo became Zaire in 1960. "Shaba" means "copper" in Swahili, the vernacular language used throughout eastern Africa where all trade was controlled by the Swahilis until the beginning of the twentieth century.

HISTORY

Until 1890, Katanga was a territory little known to Europeans. The first reported crossing of Katanga by Portuguese half-castes in 1806 has been explicitly detailed by Verbeken and Walraet (1953). But much earlier, Portuguese merchants are known to have come to Katanga regularly to negotiate for copper and ivory. The first explorers of central Africa were sponsored by the Royal Geographical Society in London, by the Belgian King Leopold II, and by antislavery movements in Western Europe. We will mention here only three of these explorers.

First of all, David Livingstone, a Scottish preacher with a passion for exploration, left South Africa to explore central Africa in 1852. He sent back to Great Britain numerous reports concerning the geography, ethnology and economic resources of the regions through which he traveled (all across the Zambezia River in Rhodesia, Angola and Tanganyika). He was preparing to penetrate into Katanga when he died of exhaustion and tropical ailments in Chitembo in the northern part of Rhodesia in 1873. Although he had not visited the deposits in the Shaba Crescent, he knew of the mineral riches there because he had seen copper trade tokens more or less everywhere, from Bagamoyo to Luanda, as well as the copper brought back by the Swahili caravans. He was the first to report on the gold from Katanga hoarded by the Sultan of Zanzibar.

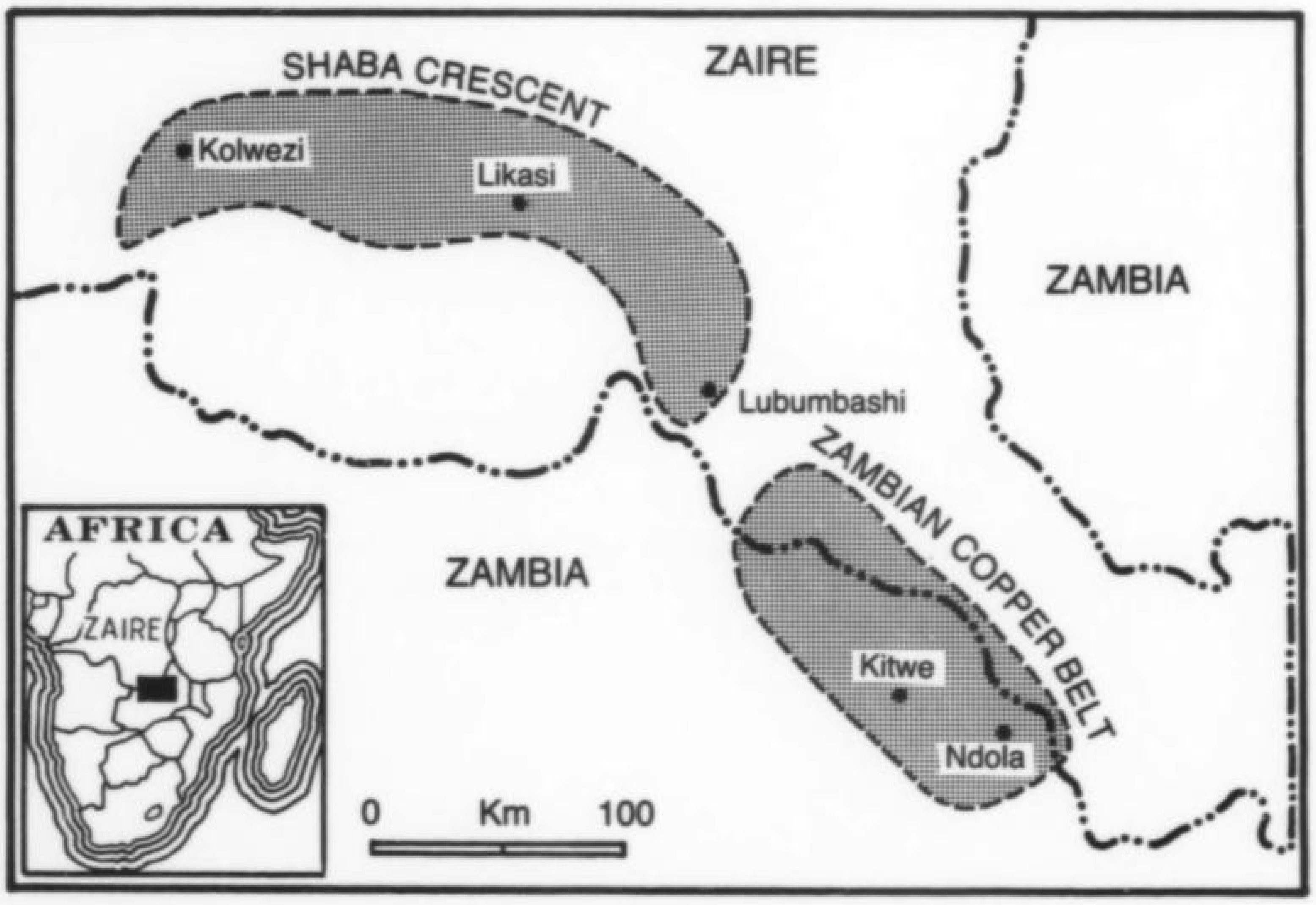


***Figure 1.* Location map.**

Next there was Henry Morton Stanley, a British, and later American, journalist sent by a New York newspaper in 1869 (the *New York Herald*) to find Livingstone, who was thought to be lost, and whom he finally encountered on November 10, 1871 in Ujiji on the eastern shore of Lake Tanganyika. Stanley was without a doubt the greatest explorer of central Africa and the first to have made the trip from Katanga to Boma, following the Zaire River (called the Lualaba in the southern and eastern parts of the country) through hostile regions with an unhealthy climate. After 1878, he worked for King Leopold II, and was not to leave Africa for good until 10 years later.

Finally there was Verney Lovett Cameron, a lieutenant in the British Royal Navy who was also dispatched in 1873 to look for Livingstone; but he arrived too late. He made the crossing of central Africa from east to west, and then returned to Katanga, where he finally settled and became an active participant in the development of mining.

These three explorers drafted heavily documented reports on the potential wealth of this mining district, and thus the desirability for Great Britain of annexing this territory. However, contrary to all logic, the Foreign Office refused to annex Katanga (at least until 1880), which was, however, an enclave in the British colonies of Rhodesia and Tanganyika. Beginning in the early 1880's, Leopold II conceived of establishing a Congo Free State which would come under his sole sovereignty. This would have been easy had it not been for Katanga, which Cecil Rhodes now wanted to recover at any cost. Rhodes tried to force the Bayeke king to recognize British sovereignty, but failed.

After several international conferences in London and Brussels, the 1884 Berlin Conference determined that Katanga would remain part of the Congo Free State. In 1885, Leopold II was finally able to proclaim the birth of a new country, the Congo Free State, but this proclamation was not to be officially recognized until 1890.

In 1886, the Congo Free State created its own army, called the Public Force, with the tasks of maintaining order, guaranteeing its frontiers and expelling the heavily armed Swahili sultans who controlled more than half of the country, and thus to put an end once and for all to the slave traffic. Leopold II then created the Katanga Company, of which Verney Cameron was to serve as president. The company financed four decisive expeditions into the Katanga interior between 1891 and 1893. These were led by Paul Le Marinel, Alexandre Delcommune, William Stairs, Lucien Bia and Emile Francqui.

The first geological and mineralogical observations were made by the Belgian geologist Jules Cornet, who participated in the last of the above-mentioned expeditions. In 1894, Cornet published the first geological description of Katanga. In his view, this was one of the richest copper districts in the world. He summarized his impressions very well, referring to the "Katanga geological scandal."

In 1899 an unusual Scottish entrepreneur, Robert Williams, created a mining, prospecting and exploitation company called Tanganyika Concessions Ltd. in Rhodesia. In principle it was established to mine gold in Rhodesia, but it had the obvious purpose of exploiting the mineral wealth of Katanga. Leopold II reacted immediately by creating the Special Katanga Committee, a chartered company with every privilege in terms of mining concessions and the assigned task of launching prospecting. It was also made responsible for protecting the rights of the owners of mines to be exploited, in other words the village heads and tribal chieftains. The Congo Free State was the majority stockholder in the Special Katanga Committee (60%); Tanganyika Concessions held the other 40%.

In 1902, the Katanga Railroad Company was established for the

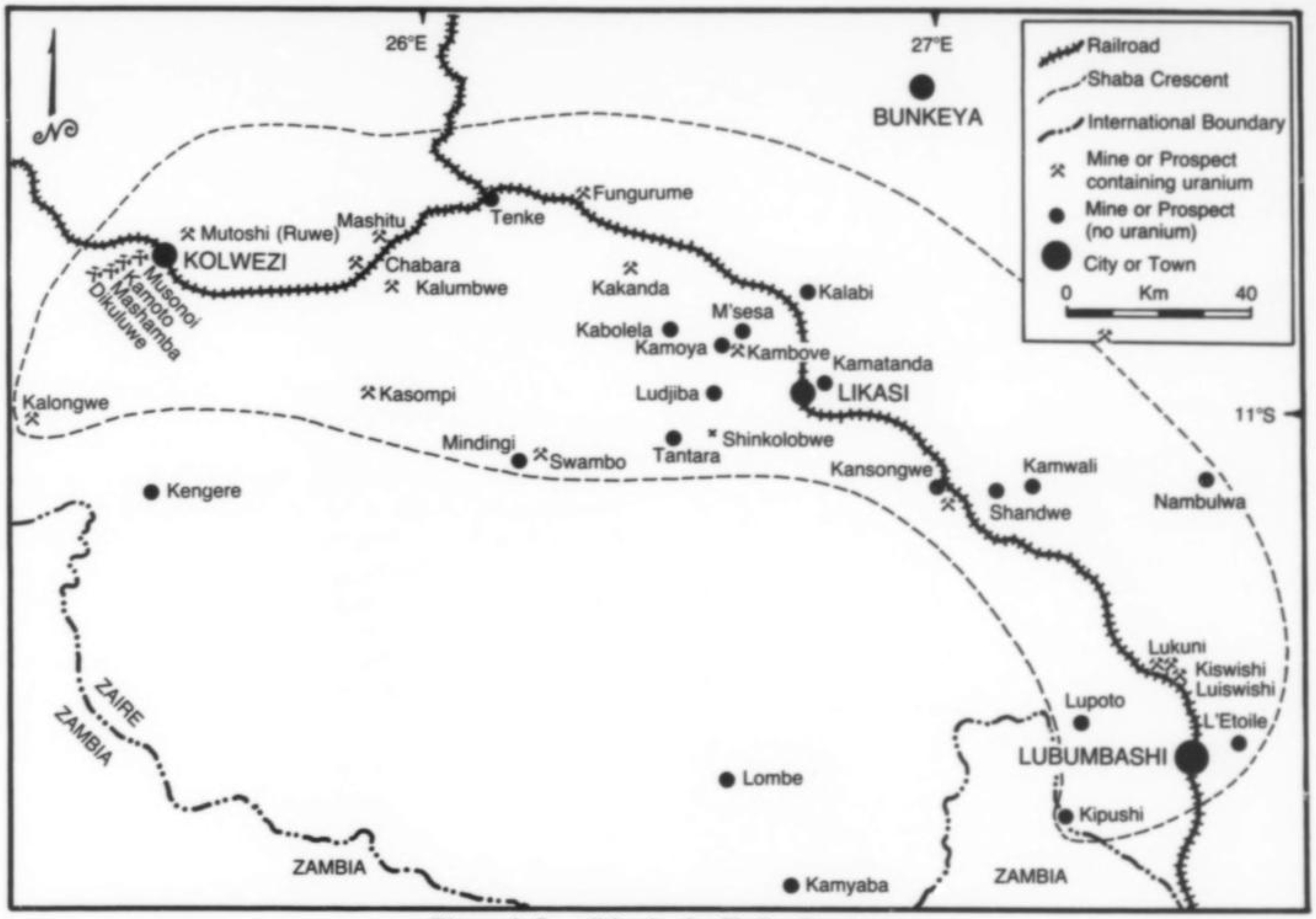


Figure 2. **Localities in the Shaba Crescent.**

purpose of linking Lubumbashi with Broken Hill in Rhodesia, and from there, via the Rhodesian and South African railroad networks, to the port of Capetown. Matters immediately began to move swiftly. In 1902 the celebrated Star of the Congo mine near Lubumbashi was opened. In 1903, Tanganyika Concessions discovered the Ruwe gold and platinum deposit (the name Ruwe derives from the initials of Robert Williams, but the site is now known as Mutoshi). It was believed that a large deposit of gold had been discovered, but this did not prove to be true. It was not known at that time that gold and platinum were but satellites of the uranium deposit, which itself was a very minor metal in the orebodies, and that the great underlying deposit was made up basically of copper and cobalt (not to be exploited until 1941).

In the same era, Chief Pande of the Basanga tribe had representatives of the Special Katanga Committee and Tanganyika Concessions taken to visit his Kambove mine (in the central sector), which was to prove one of the richest mines in the Shaba Crescent. An agreement allowing exploitation was made, with royalties going to Chief Pande. Also in 1903, the Belgian geologist and mineralogist H. Buttgenbach, of the Special Katanga Committee, discovered important mineral deposits of tin and bismuth north of Kolwezi in the Busanga-Shienzi region. Thus two zones in southern Katanga had been identified, a copper zone in the south and a tin zone in the north.

In 1905, the first convoys of wagons drawn by oxen left the port of Benguela in Angola loaded with rails and tip carts for the Ruwe gold mine. The year 1906 was the decisive one for the exploitation of the copper-cobalt deposits in the Shaba Crescent. It marked the establishment of the Union Miniere du Haut Katanga (UMHK), initially an Anglo-Belgian company in which the Societe Generale de Belgique and Tanganyika Concessions were equal partners. The word "union" reflected the desire to serve both Belgian and British interests. The local and expatriated personnel and the equipment of the Special Katanga Committee and Tanganyika Concessions at the site were transferred to Union Miniere. Thanks to the efforts of Union Miniere's exceptional founder, Jean Jadot, the company was to develop rapidly, rising to the highest international level.

In 1907, Leopold II completed his mission. He turned the country over to Belgium, but Belgium did not formally annex the territory until 1909. At that time it became known as the Belgian Congo, so remaining until the country won independence in 1960. The first geological map of Katanga was drafted by F. E. Studt in 1908. In 1909 the railway from Lubumbashi to Broken Hill (Rhodesia) was inaugurated. In 1911 the first copper smelter was opened at Lubumbashi and a second one was built two years later at Likasi-Panda. Later a second railway, the Benguela railway linking the port of Lobito in Angola to Lubumbashi and crossing all of the Shaba Crescent was laid out.

In 1921, the first shipment of uranium ore from Shinkolobwe was sent to Antwerp, Belgium. In 1925, the Kipushi mine was opened and is still operating (underground mining). By the time of World War II, Union Miniere had given up tin mining in order to focus all activity on the Shaba Crescent and the Kipushi deposit. The copper production of Union Miniere developed rapidly: 7,400 tons in 1913; 27,500 tons in 1917; and more than 300,000 tons per year in the late 1950's. Between 1940 and 1944, Union Miniere supplied to the U.S. and allied countries more than 800,000 tons of copper and all its production of cobalt, zinc, lead and uranium. Copper and cobalt production increased steadily until 1967, when Union Miniere du Haut Katanga was nationalized by the government of Zaire. The Zairian company which was its successor was known first as the General Congolese Mining Company (GECOMINES), and later became the General Quarries and Mines Company (GECAMINES). It is currently producing about 450,000 tons of copper per year. Its reserves are tremendous and production should not decline between now and the end of the century.

After 1960 the Belgian Congo became first of all the Republic of the Congo, and then the Democratic Republic of Zaire.

Copper in Katanga

Copper has been known to exist in southern Katanga since ancient times (Hemptinne, 1926). All of the copper artisans, from the miners to the master casters and the wiremakers, were called "copper eaters." After the local Paleolithic era, the use of iron and then copper must have represented an important stage in the development of civilization in central Africa. It is known that at the end of the seventh century B.C., the peoples of the Middle East were already producing copper from green ores (malachite and chrysocolla). Had the natives of the southern Katanga lent them their techniques, or did they invent them independently? In any case, some tribes in the Shaba Crescent mastered copper metallurgy several hundred years ago, just as other neighboring tribes had mastered ferrometallurgy.

Craft items of impure copper were produced exclusively from crushed malachite, a mineral which is particularly abundant in the Shaba Crescent, although it is rarely found in the Zambian Copper Belt. Generally speaking, the most important deposits of malachite originally appeared as outcroppings at the summit or on the sides of the hills. In fact, native mining work was developed in all parts of the Shaba Crescent, in the western sector (to the west of the Lualaba River) as well as in the central sector (between the Lualaba and the Lufira River) and in the eastern sector (to the east of the Lufira). The workings were small quarries a few meters deep and trenches following the malachite veins, and also underground mines with shafts (some 35 meters deep have been found) and galleries (some of 20 meters reported). In 1883, an explorer named Dr. Reichard visited the native Luishia mine. In the old native works in the Likasi mine, the malachitized skeleton of a miner crushed by rockfall was found in a gallery (Buttgenbach, 1947).

Copper was obtained by a process involving the roasting and reduction of the malachite, using special wood and charcoal in small blast furnaces equipped with rudimentary bellows made of antelope skin. Sometimes this process was followed by a supplementary refining operation in a small furnace also equipped with bellows and fueled exclusively with charcoal. The copper was then poured into molds to produce "cross stones" and ingots. "Cross stones" (called "Katanga crosses" by numismatists) were the famous trade tokens in the form of a St. Andrew's cross, ranging in dimension from a few centimeters to several decimeters, depending on the currency value involved. These coins, produced above all in the eastern sector, were used throughout central Africa until the end of the nineteenth century. Ingots were produced typically in the form of an "I" in cylindrical bars, or more simply, in masses of standard weight. The latter were sold as such or converted on the spot by local artisans into ritual, utilitarian or simply decorative objects: copper wire on spools, bullets, rings, bracelets, various tools and instruments (forged copper hoes etc.), and ornaments. Mention should be made here of the wire-drawing technique perfected by the Bayeke wiremakers. In view of their rudimentary technique it was an extraordinary accomplishment. By dint of endless patience they produced wire calibrated to a diameter of a half millimeter.

The copper market in southern Katanga flourished in the nineteenth century. It should, however, be considered within a much more general trade context—that including ivory (worth more than copper, by weight), salt (abundant at certain sites in southern Katanga) and, alas, slaves. In addition to copper, the sale of raw malachite (a mineral reported from Katanga as early as 1789) was also common. Trade operations were carried out by caravans of camels and bearers transporting cloth, weapons, gunpowder and foodstuffs. These caravans came to Tanganyika and Katanga from the east, from Bagamoyo on the coast and from the island of Zanzibar. The Swahilis, a people made up of Arabs and Arabicized half-caste blacks who controlled all of East Africa, had an absolute monopoly on this trade. The wealth of the Sultan of Zanzibar was legendary. From the west, these caravans came across Angola, either from Sao Paolo de Loanda (currently Luanda, the capital of Angola), or from the region around the mouth of the Zaire (or Congo) River, particularly Sao Antonio do Zaire (M'Pinda) and Boma, which were great trade centers. Here the trade was controlled by Portuguese and half-caste merchants. The copper from the Atlantic coast was then re-exported either to other African countries (Benin, Ivory Coast, Ghana) or by sea to Western Europe. There were also caravans coming from northwestern Katanga (Kasai, Lomami) and the southeast, from as far away as Lake Nyassa. One can assume that thousands of tons of copper were marketed in this way, at least from the sixteenth century on.

The village of Katanga (eastern sector of the Shaba Crescent) was already known for its copper market in the eighteenth century, but the name given to the entire region is because of the authority and the scope of influence of the head of the local tribe, Chief Katanga, during the nineteenth century. Toward 1850, the Bayeke ethnic group, made up above all of merchants and warriers from Tanganyika, invaded a large part of Katanga and subjugated all of the tribes in the central and eastern sectors. This group monopolized copper exports from both sectors to its own benefit, while participating actively in production and particularly in wire making. Bunkeya (outside the Shaba Crescent, to the north of Likasi) became the capital of the Bayeke kingdom, and the town subsequently became the leading caravan center in Katanga in the second half of the nineteenth century.

Uranium in Katanga

Uranium was identified in the Shaba Crescent for the first time on January 22, 1913 at the Luiswishi copper mine, outside the copper and cobalt-bearing orebodies, in the clayey talcose rock filling a fault. This was a yellow-orange and black ore, compact masses of "gummites," curite and uraninite. This uranium deposit was of little economic importance. Mineralogically, it yielded cubic crystals of uraninite, uraninite-curite pseudomorphs and, much later, the first sengierite, and doubly terminated crystals of vandenbrandeite.

The Shinkolobwe deposit was discovered by chance on April 12, 1915 by Robert S. Sharp, an employee of Union Miniere, in the course of topographic work on small copper deposits which had been known since 1902. These deposits, to which the name the "Shinkolobwe group" had been given, had already been subjected to the beginnings of mining by natives. Sharp was preparing to place a marker stake on an outcrop of cellular siliceous rocks forming an overhang of 10 or so meters in the area when he noticed some yellow material similar to that which he had already seen in Luiswishi. He had several trenches dug and they confirmed the outcrop of a vein of uranium ore. Only the westernmost deposit in this group of copper ores proved to be uranium-bearing. It was marked out under the name Shinkolobwe, although the site was called Kasolo and the type of ore noted on the marker stake was "radium," with no reference to uranium or copper. Later, the marker stake placed at the summit of the outcropping of cellular siliceous rocks was renamed Kasolo, and it was also under this name that the concession was registered with the Special Katanga Committee. However, the mine still retains the name Shinkolobwe.

Uranium was subsequently found sporadically in various copper and cobalt-bearing deposits, but most frequently in the form of indications, either in the course of the exploitation of mines or during surface prospecting or drilling for survey purposes. Along with other discoveries, we might note the discovery made in Kalongwe in 1930 (copper mine in which uranium was preponderant), and those made in the Musonoi Extension and in Swambo in the 1950's.

Of all the uranium-bearing deposits in the Shaba Crescent, only the one at Shinkolobwe has been commercially exploited. This is an average deposit on an international scale (several tens of thousands of tons of uranium metal), but with a rather high grade. Mining was undertaken between 1921 and 1936 exclusively for radium, and then between 1944 and 1959 for uranium. The mining, first done by the open pit method, was gradually converted to underground mining at the beginning of the 1950's.

Figure 3. **A view of the Shinkolobwe mine, 1930's.**

By 1943, uranium had become a strategic metal, and all stocks of rich ore were shipped to the United States. It is a well known fact that the atomic bomb dropped on Hiroshima (August 6, 1945), which made it possible to end World War II, was manufactured using Shinkolobwe uranium. By 1959 the main mine deposit had been exhausted and it was decided not to mine the adjacent deposit, called Shinkolobwe-extension, which is deeper and less economical.

GEOLOGY

General Geology

The subsoil in Shaba is made up of rocks formed between the Archean era (3 billion years ago) and the present time. From the mineralogical point of view, it is the so-called "Katanga System," sedimentary rocks dating back about a billion years (Upper Proterozoic), which are of the greatest interest. In fact, they constitute the basement rocks of the Shaba Crescent, a polymetallic district of major importance, with mineral deposits of copper, zinc, iron, lead, cobalt, cadmium, germanium, uranium, nickel, silver, barium and gold, accompanied by very small quantities of platinum, palladium, molybdenum, selenium, cerium and others. It is in the Katanga System deposits that the majority of the known minerals in Shaba have been found. We will, therefore, discuss only this system (François, 1974 and 1987).

About 1.2 billion years ago, southern Shaba was a vast structural basin, triangular in form, bounded on the east and the northwest by two converging mountain chains, the Fort Roseberry and Kibara massifs. This "gulf of Shaba," the bottom of which was gradually sinking, was covered by one or several vast lagoons of very salty water, bounded on the south by a sea. In the lagoon, due to a hot climate, a succession of more or less sandy clayey dolomitic (deposited during humid periods?) and dolomitic muds, with the development of algal reefs and possibly evaporite beds (deposited during dry periods?) about 1500 meters thick, was deposited. This is known as the "Roan Supergroup."

Subsequently, the sea advanced toward the north and covered the gulf. Then a complex of more or less dolomitic clayey and sandy muds was deposited, thanks to a humid and rather cold climate. The thickness of these sediments might exceed 5,000 meters in the southern part of the gulf. At the base and in the middle, strata of gravel in a clayey matrix (which might be of glacial origin, resulting from a temporary cooling of the climate) can be observed. Some hot and dry climatic episodes are reflected in the deposit of calcareous or dolomitic muds. All of these sediments make up the Lower and Upper Kundelungu "Supergroups."

The compaction of these sediments due to their own weight, with the expulsion and thus circulation of the interstitial waters, converted these loose materials into compact rock. It is for this reason that the Roan is currently made up of resistant formations of dolomites and dolomitic shales, alternating with relatively plastic chloritic pelitic formations and perhaps very plastic salt beds. The two Kundelungu Supergroups begin with a conglomerate overlain by more or less dolomitic clayey or sandy shales with infrequent horizons of dolomite or limestone. These carbonate horizons only take on substantial thickness in the southern part of the mining zone (in the Lower Kundelungu Kakontwe limestone), and in the northern part (in the Upper Kundelungu Lubudi limestone).

Seven hundred million to 620 million years ago, the Katangan formations were subjected to several phases of tectonic movement. In the northern portion and on the boundaries of the gulf, these movements were weak and the strata remained subhorizontal. In the center and toward the south, on the contrary, the strata were strongly folded in a series of anticlinal and synclinal structures. Massifs were superimposed one upon the other all along the faults, resulting in thrusting

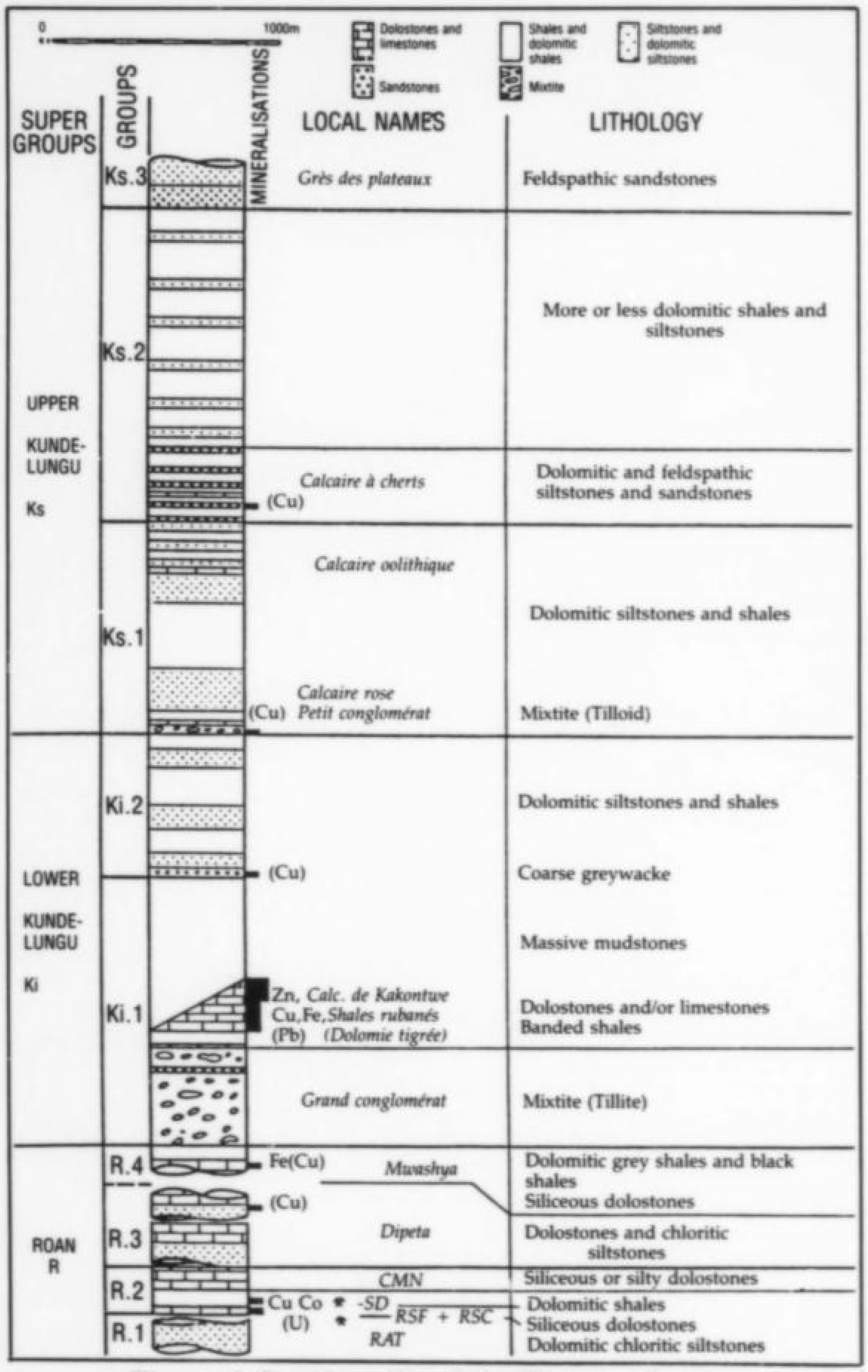


***Figure 4*. Stratigraphy of the Katanga System (from François, 1987).**

which progressed from the south toward the north at first, and then subsequently from the north toward the south. Major oblique faults cut the folds at an acute angle.

One of the results of these deformations was to bring the Roan formations closer to the surface, either along the axis of the anticlines, in the straddling massifs, or moving up along the oblique faults. Simultaneously, the plastic formations of the Roan began to move and broke up, while the more resistant dolomitic complexes, no longer having support, broke into pieces bounded by transverse faults, which range in length from several meters to several kilometers. The whole makes up a megabreccia with a tremendous volume (see Figs. 5, 8 and 9).

The mechanism which caused all these movements is poorly understood. Some tectonic structures may be related to now-gone evaporite deposits. A part of the folds and the north-south thrusts could be explained by a slippage toward the north of the Katangan formation, caused by an uplift of the substratum to the south of the Zambian frontier. Later deformations seem to be the result of movements at great depth in the substratum. The result thereof is a very unusual tectonic structure, hardly any other examples of which are to be found on the surface of the earth.

Within the Katangan System, stratiform copper and cobalt-bearing mineral deposits are by far the most important. They are again located in the "Mines Group," which is the oldest resistant dolomitic complex in the Roan. At the base of this group, two finely stratified mineralized levels are found. The first, comprising the lower orebody, is a siliceous dolomite 10 to 15 meters thick. The second, or upper orebody, is a sandy dolomitic shale 5 to 10 meters thick. They are separated by 15 meters of massive sterile dolomite which is algal in origin. They are very regular but consistently sharply interrupted by transverse faults marking the boundary of the Mines Group fragments. At depth, the mineralization consists of finely scattered chalcocite with a little bornite, accompanied in some horizons (in general, at the base of the upper orebody) by carrollite. This appears to be a primary ore which has not been secondarily enriched.

The mineralization is far from consistent. Some of the Mines Group fragments are richly mineralized (about 5% copper). Others, much more numerous, are poor or practically barren. It appears that, prior to the dislocation of the Mines Group, the mineral deposits were distributed in patches, with their frequency being related to the facies of the rocks involved. Weathering transforms the copper sulfides into malachite, sometimes accompanied by silicates (chrysocolla, dioptase, bisbeeite) and phosphates (pseudomalachite, libethenite, cornetite). The carrollite changes into heterogenite and sphaerocobaltite.

The origin of these mineralizations has not as yet been identified. They appear to be relatively early. There may have been a replacement of the pyrite deposited along with the sediment by the copper and cobalt sulfides, brought in by brines during the consolidation of the rocks (diagenesis). Volcanic action seems to have been involved only to a very modest extent.

Very locally, the base of the lower orebody contains auriferous uraninite, sometimes accompanied by nickel sulfides. This is probably a primary mineralization, distributed in patches which are tiny and widely scattered. When subjected to weathering, the uraninite gives rise to a large number of secondary minerals, located either in the lower orebody or more or less distant from it, along faults or other horizons in the Mines Group. The greater the distance from the lower orebody, the fewer these occurrences become, which would seem to indicate that it was indeed here that the primary uraninite was deposited. (The paragenesis of these minerals will be discussed later.)

Three occurrences of copper-zinc vein deposits are known. They are located in the Kakontwe limestone (Lower Kundelungu Supergroup), at the site where this formation is interrupted or crossed by a fault. At some depth, in Kipushi, cadmium-rich sphalerite, pyrite, chalcopyrite, bornite and galena can be observed, along with chalcocite, renierite and native silver in small quantities. Weathering yields numerous minerals: malachite, hemimorphite, cerussite, veszelyite, aurichalcite, and many others. The origin of these veins has not as yet been clearly explained.

In addition to the copper-cobalt orebodies mentioned above, there are numerous other copper, iron and barite deposits, but they are generally without economic value. Copper occurs (generally as chalcopyrite, changing into malachite) below the Mines Group (secondary mineralization *per descensum*), in diffuse impregnations and thin stratiform horizons in the upper Roan groups (Dipeta and Mwashya), and in the conglomerates or sandy pelitic rocks on the two Kundelungu formations. Iron occurs in the form of hematite, limonite or magnetite, in the upper Roan group (Mwashya), in the Kakontwe limestone, and along faults. Some occurrences of barite have been found in the fault zones.

The Shaba Crescent represents more than three-quarters of the South Equatorial cuprocobaltiferous metallogenic province. The Zambian Copper Belt, a district which overlaps Shaba a bit, represents the balance. The orebodies in Shaba and Zambia have the same sedimentary origin, are of the same Upper Proterozoic era, have the same original stratiform arrangement and the same distribution of sulfides in mineralized patches. They are probably contemporaneous, but differ in their lithology and their tectonic structure. Where the lithology is concerned, dolomite is abundant in the gangues of the mineral deposits in Shaba, while it is almost entirely lacking in those in Zambia. Where the tectonic structures are concerned, the dislocation into fragments

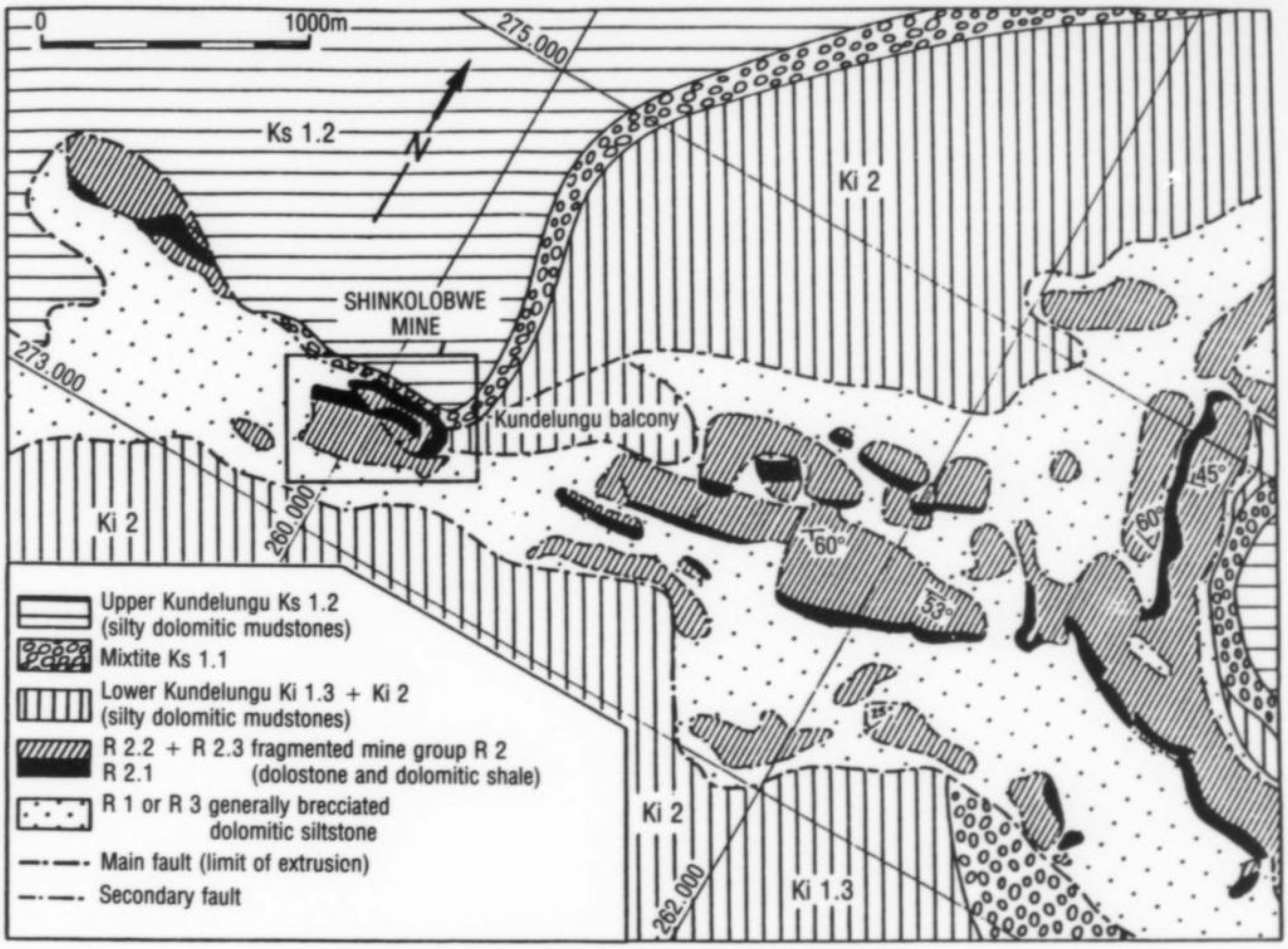


***Figure 5.* Geology of the western portion of the Shinkolobwe diapir (from François, 1987).**

characteristic of the Mines Group is not found in Zambia. This is perhaps due to the absence here of plastic salt formations between the basement rocks and the orebodies. Whatever the case, the presence of dolomite and advanced tectonic effects on the deposits in Shaba explain the extraordinary development of secondary ores, whether uraniferous or not, which are not found in the Zambian Copper Belt, although the climate there is the same. In particular, the malachite in Shaba reveals a development and an abundance only found elsewhere in the deposits mined in the Urals in the last century. Moreover, in the majority of the uranium-bearing deposits, an extraordinary paragenesis of secondary uranium-bearing ores has developed in the oxidation zone, with numerous new mineral species, some of which have never been found elsewhere.

Uranium Deposits

All of the uranium deposits in the Shaba Crescent have been associated with the Mines Group, in direct or indirect relation with the lower orebody. The major modes of emplacement are as follows:

1. In the heart of an anticline with two more or less complete flanks (as at Kalumbwe and Kasompi).
2. Along the axis of an anticline with the southern flank astride the northern flank (as at Ruashi, Kiswishi, Luiswishi, Luishia, Kambove-West, Fungurume, Chabara and Mashitu).
3. Along the axis of an anticline with the northern flank astride the southern flank (as at Kakanda-South).
4. In an outlying fragment isolated in the heart of a syncline (as at Mutoshi, Musonoi-Extension, Kamoto-East, Kamoto-Main and Mashamba).
5. In extrusive structures (as at Shinkolobwe, Swambo and Kalongwe).

François (1974) reported 22 occurrences of uranium in the Mines Group, including seven in exploited or known deposits, two in probable deposits, three in possible deposits, and ten known only as traces. Some new occurrences have been discovered since 1974.

In the Zambian Copper Belt, uranium is also frequently found, but only as traces (in southern Shaba, reported in Musoshi and Tshinsenda; and in Zambia, reported in N'Kana and Luanshya).

Shinkolobwe

Shinkolobwe is certainly one of the most famous uranium mines in the world. In the course of World War II, it was the only large operational uranium mine in the free world, with rich stockpiles of ore ready for shipment. The richness, diversity and importance of its primary and secondary mineralization make it extraordinary; it yields an assemblage of primary and secondary minerals which exists nowhere else. In fact, Shinkolobwe represents a mineralogical high point on our planet, in the same way as Franklin, Långban, Lovozero, Khibina, Pribram, Jachymov, Tsumeb and Broken Hill, Australia.

The description of new Shinkolobwe species based on old samples is still in progress. Research was undertaken several years ago at the B.R.G.M. (Bureau of Geological and Mining Exploration) in Orleans, France. Especially active research is still under way at the Royal Museum of Central Africa in Tervuren, Belgium, in collaboration with the University of Louvain-la-Neuve in Belgium (Deliens *et al.*, 1981, 1984) as well as the Department of Mineral Sciences at the Smithsonian Institution in Washington, D.C. A mineralogical expedition to explore the old mine dumps and the accessible parts of the ancient quarry and the mine galleries located above the water table would probably result in the collection of additional new species. With regard to the species known to date, the situation is as follows: at least 28 primary species are known, only one of which is uranium-bearing; and 50 secondary species of uranium-bearing minerals have been identified (of which 28 have been described for the first time, and 10 or so are still unique to the deposit). There are also 14 non-uranium-bearing species. It

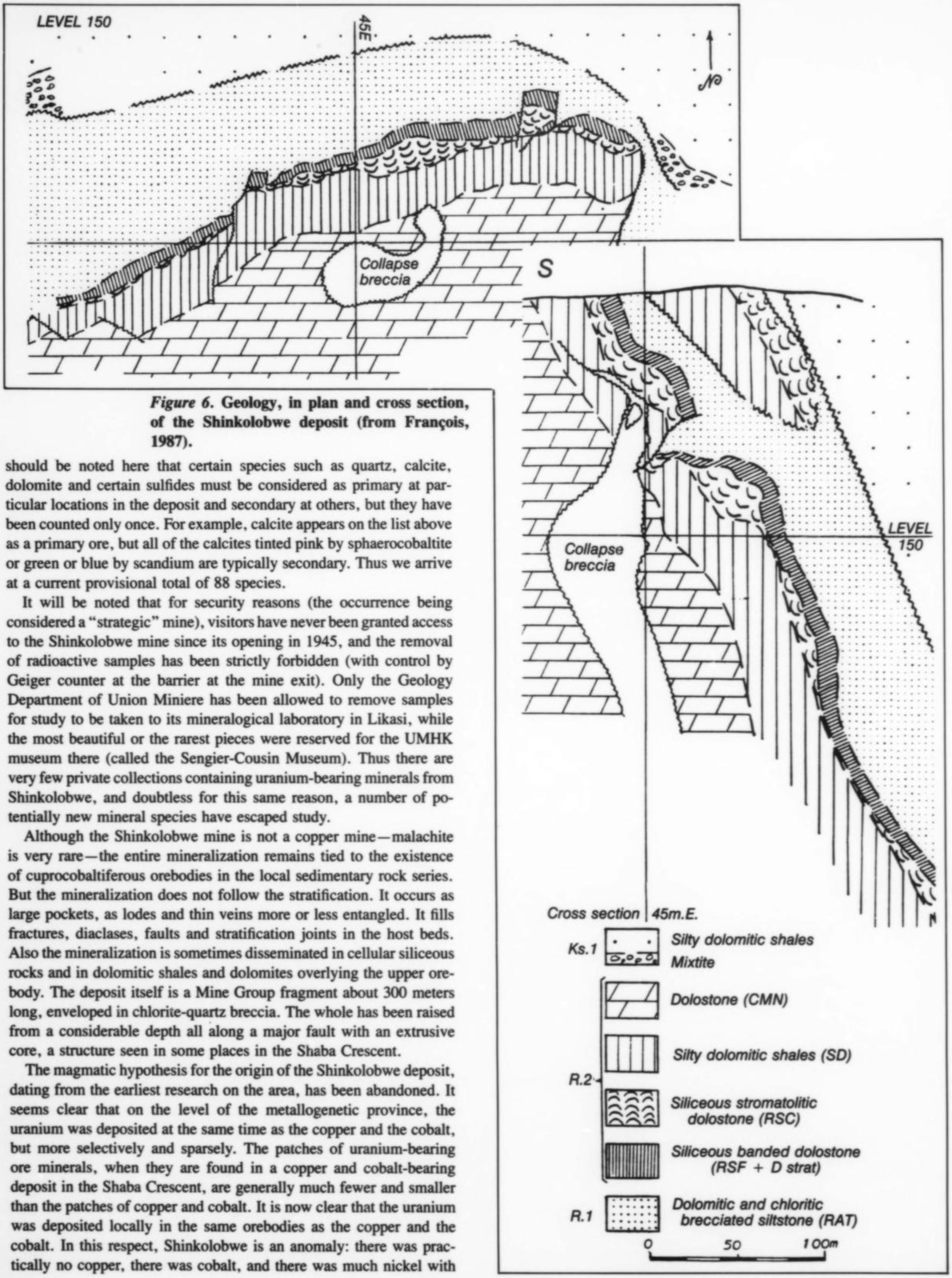


Figure 6. **Geology, in plan and cross section, of the Shinkolobwe deposit (from François, 1987).**

should be noted here that certain species such as quartz, calcite, dolomite and certain sulfides must be considered as primary at particular locations in the deposit and secondary at others, but they have been counted only once. For example, calcite appears on the list above as a primary ore, but all of the calcites tinted pink by sphaerocobaltite or green or blue by scandium are typically secondary. Thus we arrive at a current provisional total of 88 species.

It will be noted that for security reasons (the occurrence being considered a "strategic" mine), visitors have never been granted access to the Shinkolobwe mine since its opening in 1945, and the removal of radioactive samples has been strictly forbidden (with control by Geiger counter at the barrier at the mine exit). Only the Geology Department of Union Miniere has been allowed to remove samples for study to be taken to its mineralogical laboratory in Likasi, while the most beautiful or the rarest pieces were reserved for the UMHK museum there (called the Sengier-Cousin Museum). Thus there are very few private collections containing uranium-bearing minerals from Shinkolobwe, and doubtless for this same reason, a number of potentially new mineral species have escaped study.

Although the Shinkolobwe mine is not a copper mine—malachite is very rare—the entire mineralization remains tied to the existence of cuprocobaltiferous orebodies in the local sedimentary rock series. But the mineralization does not follow the stratification. It occurs as large pockets, as lodes and thin veins more or less entangled. It fills fractures, diaclases, faults and stratification joints in the host beds. Also the mineralization is sometimes disseminated in cellular siliceous rocks and in dolomitic shales and dolomites overlying the upper orebody. The deposit itself is a Mine Group fragment about 300 meters long, enveloped in chlorite-quartz breccia. The whole has been raised from a considerable depth all along a major fault with an extrusive core, a structure seen in some places in the Shaba Crescent.

The magmatic hypothesis for the origin of the Shinkolobwe deposit, dating from the earliest research on the area, has been abandoned. It seems clear that on the level of the metallogenetic province, the uranium was deposited at the same time as the copper and the cobalt, but more selectively and sparsely. The patches of uranium-bearing ore minerals, when they are found in a copper and cobalt-bearing deposit in the Shaba Crescent, are generally much fewer and smaller than the patches of copper and cobalt. It is now clear that the uranium was deposited locally in the same orebodies as the copper and the cobalt. In this respect, Shinkolobwe is an anomaly: there was practically no copper, there was cobalt, and there was much nickel with

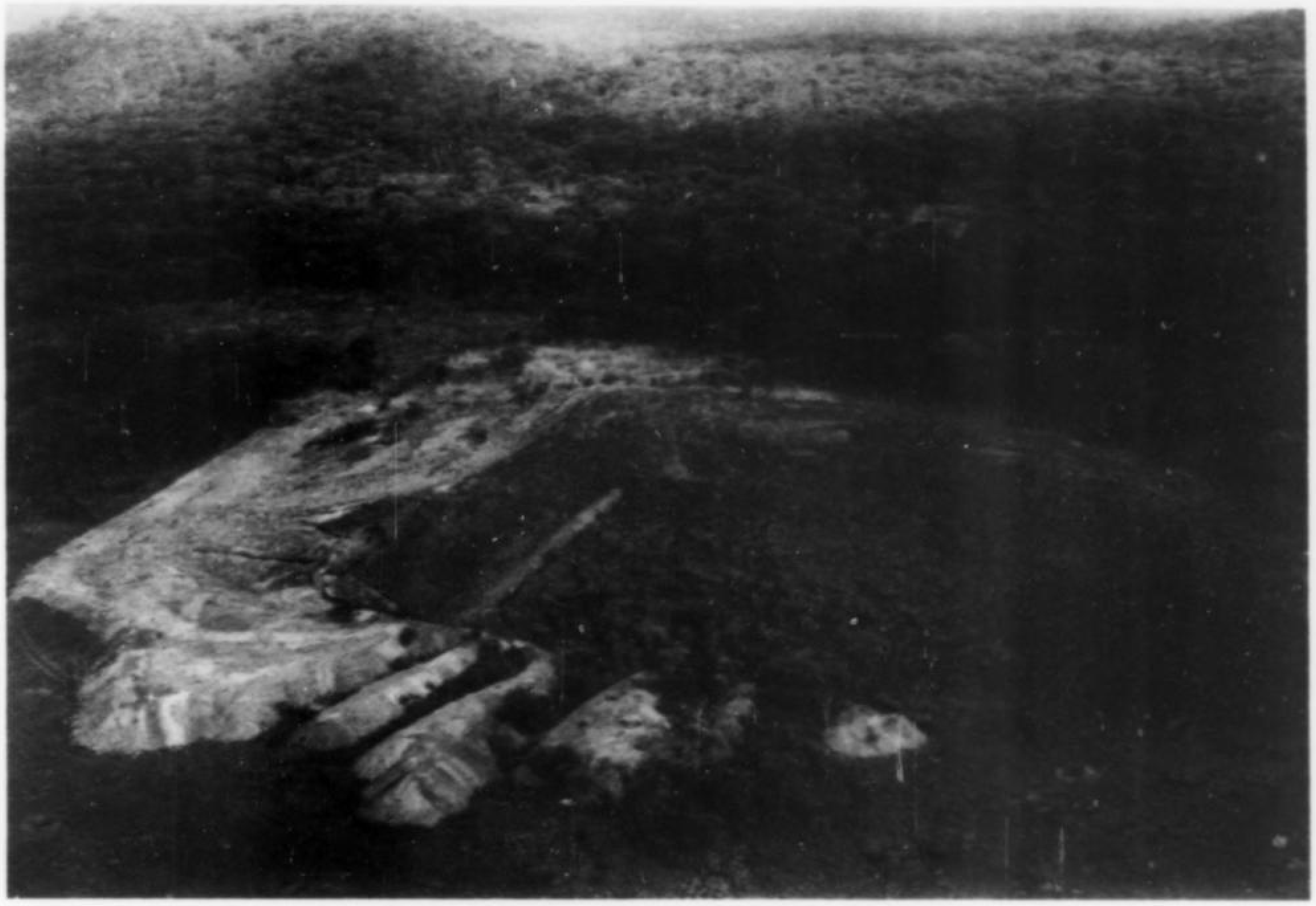


***Figure 7.* Trenches at the Swambo mine site, 1967. Photo by A. François.**

some uranium present. The initial mineralization in Shinkolobwe could have been diagenetic or even syngenetic, but in any case preceded the tectonic movements. During these movements and the raising of the mineralized debris along the length of the extrusive structure, the uranium and the other metals could have been entirely or partially mobilized again, thus giving birth to deposits in lodes and veins.

In recent years, researchers (Audeoud, 1982) have proposed a volcanic origin, not only for the uranium in Shinkolobwe but also the copper and cobalt in all of the deposits throughout the metallogenetic province. It is a fact that sediments of volcanic origin (cinders, lava) have been identified in the upper formations of the Roan. Farther down, traces of cinder have been detected locally at the base of the lower orebody. At the present point in our knowledge, we believe that direct volcanic origin of the mineral deposits should be excluded, but that a distal volcanic influence was present during deposition of metals in the lagoonal environment.

In any case this is what emerges from the syntheses by François (1974) on the geology of the Shaba Crescent, as well as the works of the geologist N'Gongo Kashisha (1975) of the GECAMINES Company.

The surface alteration of the Shinkolobwe deposit took place in a relatively recent epoch. The radiogenic lead in the secondary galena is of Tertiary age. The meteoric water bath affecting a large part of the weathered zone led to the oxidation and decomposition of a part of the primary mineralization, with ions being put into solution and circulation and the episodic re-precipitation of new salts and their hydration according to local conditions. The weathering of the deposit developed under exceptionally favorable conditions; these include the multiplicity of the veins and little seams of uraninite and the primary sulfides all along the upper part of the oxidation zone, the tropical climate, the outcropping of the deposit on the surface (particularly the cellular siliceous rocks, a veritable chimney for channelling the meteoric waters), the very low water table (between 70 and 80 meters), the carbonate nature of the gangues, with many liquid inclusions on certain levels, and the circulation of carbonated and siliceous meteoric waters in the deposit.

It is known that uraninite is readily altered in an oxidizing aqueous environment. Its alteration in situ is accompanied by the transport and precipitation of ions incorporating tetravalent or hexavalent uranium, as a function of the pH of the solutions, their temperature, the range of all of the ions involved, their relative concentration, etc. These ions range from simple ones like the uranyl ion $(UO_2)^{+2}$ and the ion $[(UO_2)(OH)]^+$ to complex carbonated, phosphated, silicated and sulfated ions such as $[(UO_2)(CO_3)_2]^{-2}$, $[(UO_2)(CO_3)_3]^{-4}$, $[(UO_2)(SO_4)_2]^{-2}$ and $[(UO_2)(SiO_4)]^{-2}$. In the Shinkolobwe oxidation zone, there was every potential for the combination of the ions mentioned above with the following metallic cations: Ca, Ba, Mg, Cu, Pb, Mo and V, as well as those of the rare earths Ce, La, Y, Gd and Dy.

It will be noted that nickel is never found in the composition of secondary uranium-bearing minerals. Where cobalt is concerned, it is found at Shinkolobwe solely in the secondary deposits in the form of oursinite. Finally, there is the presence of submetallic elements in the mineral deposits in Shinkolobwe: selenium, and in a much smaller proportion, tellurium, and on a trace level, scandium. The lead found in the secondary mineralization is entirely radiogenic.

Swambo

Swambo is situated 36 km to the west of Shinkolobwe, near the Midingi mine. There is uranium-bearing mineralization here of the same type as that at Shinkolobwe. The mineralization is located in a fragment of the Mines Group included in a megabreccia of the Roan. This fragment has risen along a major fault bounded on both sides by the Kundelungu formation. More precisely, the uranium is located along the West fault which terminates the fragment on the west. Uranium is accompanied by cobalt, nickel and precious metals in the orebody. The oxidation zone is strongly developed; and there is massive uraninite still present throughout the oxidation zone, with the sulfides of Cu, Co and Ni, as at Shinkolobwe.

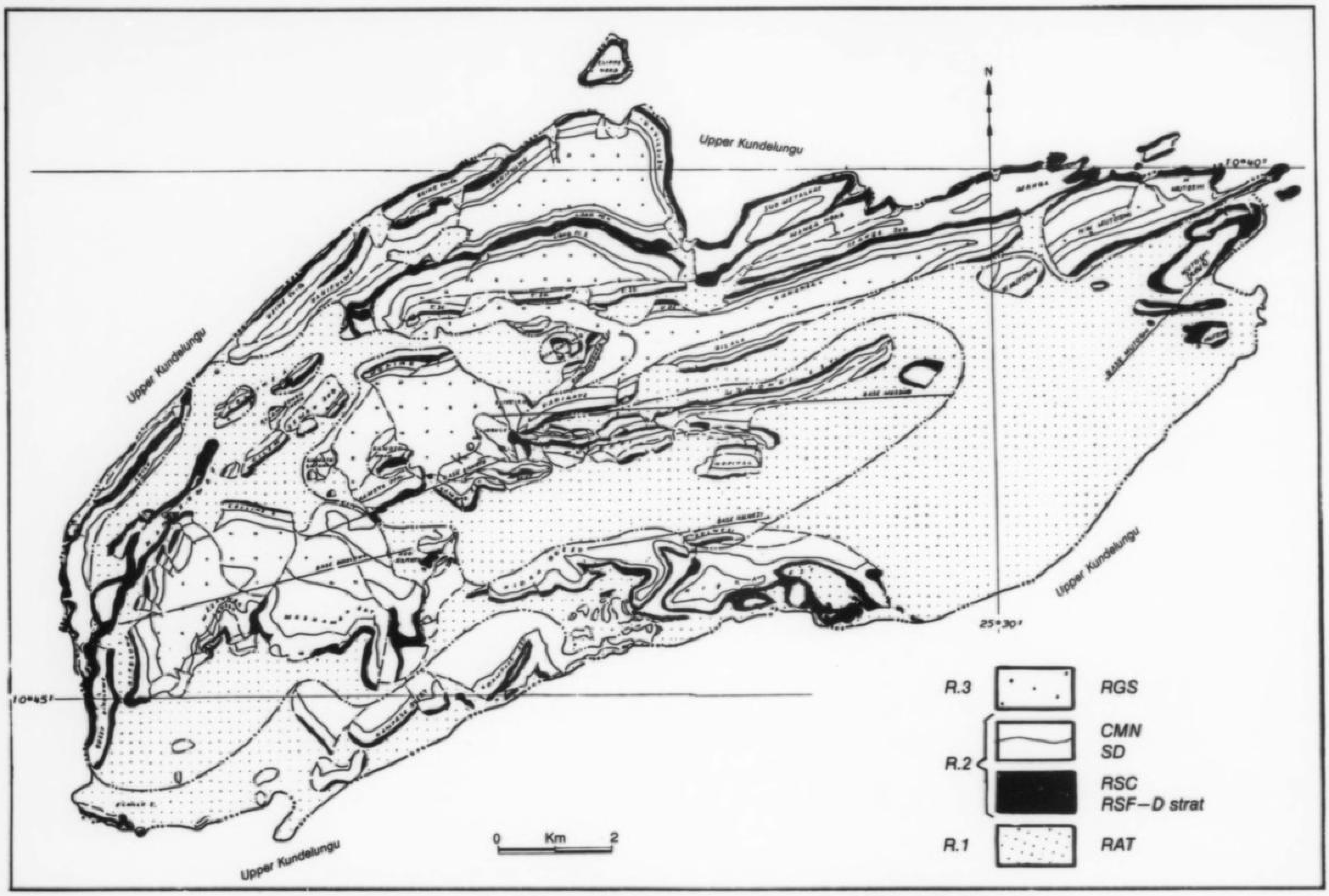


***Figure 8*. Geology of the Kolwezi klippe (from François, 1987). The Mutoshi mine is at far right and the Dikuluwe mine is at far left (see Fig. 2).**

Research was done by means of drilling in 1957, and then a mine shaft was sunk in 1958. A number of underground galleries were also excavated, but in the end the mine was not brought into production. Swambo is a model small uranium deposit which has yielded the most beautiful soddyite crystals seen to date, as well as a new species, swamboite. Gold is also present, as small rods and veins. It is clear that many other species would be found if the mine were exploited.

Musonoi

The Musonoi mine, located on the western end of the Shaba Crescent, is part of the Kolwezi klippe, a lens of Roan megabreccia 22 km long, 10 km wide, and 1.2 km thick at its maximum. It lies over the Kundelungu formation. The Musonoi mine is a very large copper and cobalt mine of which only the oxidation zone has been exploited to date. In the western sector of this mine, showing heavy tectonic faulting (called the "Musonoi extension") a uranium-bearing zone was found in the 1950's in the lower copper-cobalt orebody. Selenium is closely associated with the uranium. This zone has a length of approximately 100 meters and a height of about 50 meters.

The mineralization at Musonoi is truly remarkable. It contains an assemblage of beautiful secondary minerals, including especially torbernite and cuprosklodowskite, which are probably the finest examples of their species in the world. Several new mineral species have been found there as well. Unlike the situation in the Shinkolobwe and the Swambo deposits no primary uraninite remains in the oxidation zone here. Therefore the secondary minerals in the uranoseleniferous pocket in Musonoi never appear on massive uraninite, but only on dolomitic or siliceous matrix.

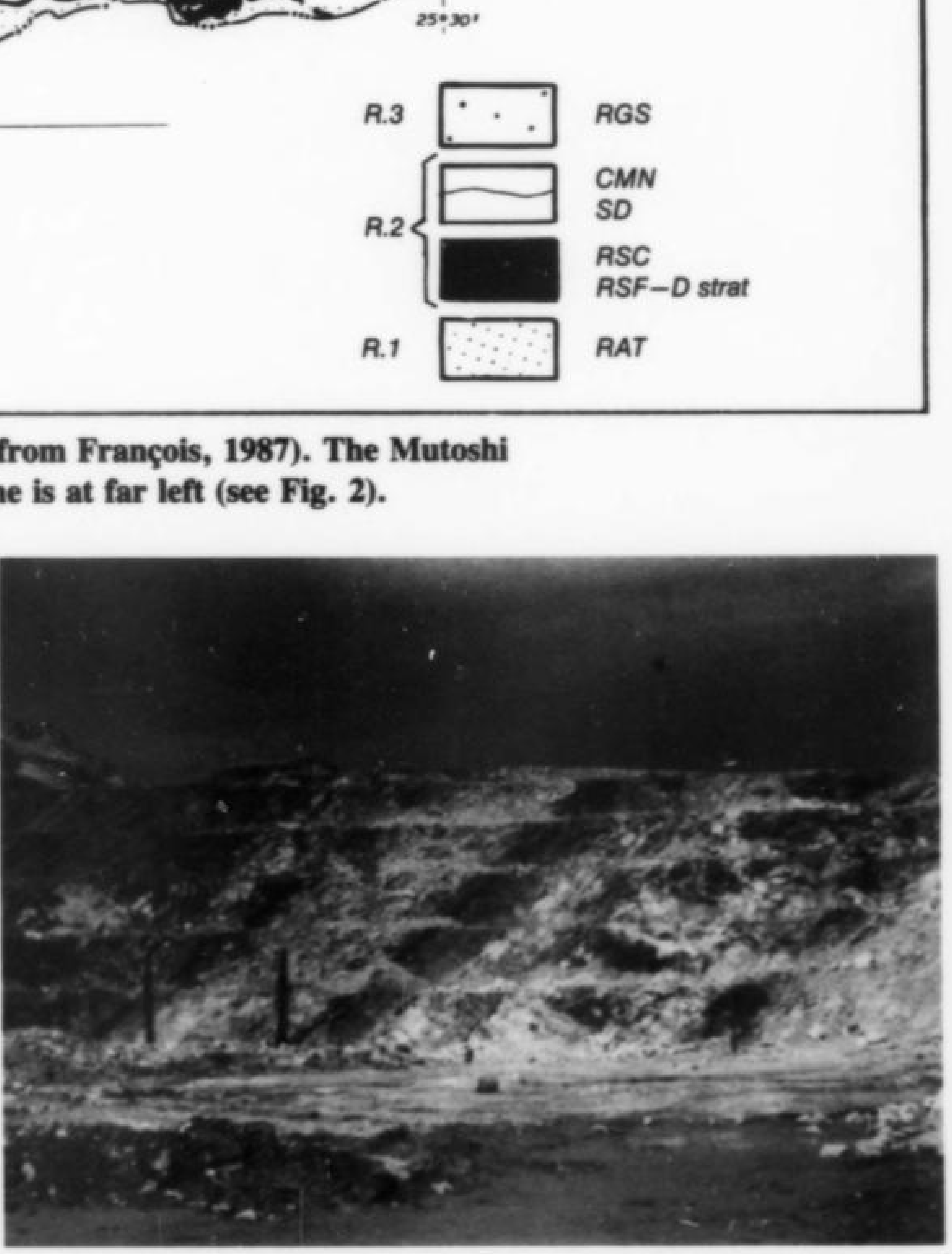
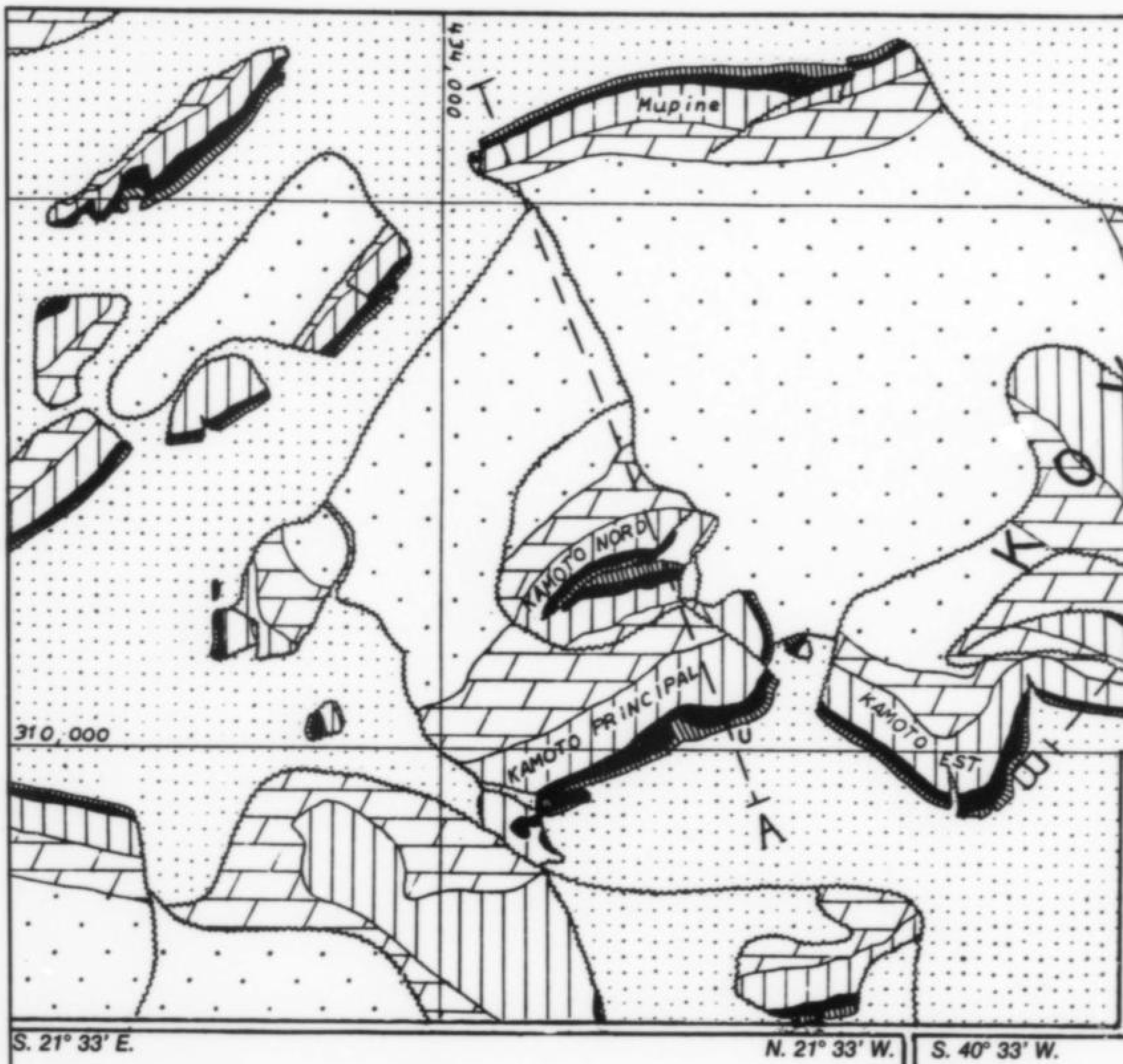


***Figure 9*. The Kamoto mine, 1969.**

Kamoto

Located in the vicinity of Musonoi, the Kamoto-East mine is particularly remarkable for the presence of a restricted accumulation of uraniferous mineralization. The oxidation zone includes a series of rare uranyl and rare earth minerals such as kamotoite-(Y), shabaite-(Nd), françoisite-(Nd) and schuilingite; the latter species was already known in the Menda and Kasompi deposits (west of Likasi, in the central area of the Shaba Crescent). All these minerals were found associated with uranophane, masuyite and some undetermined species, as crusts on uraninite matrix.



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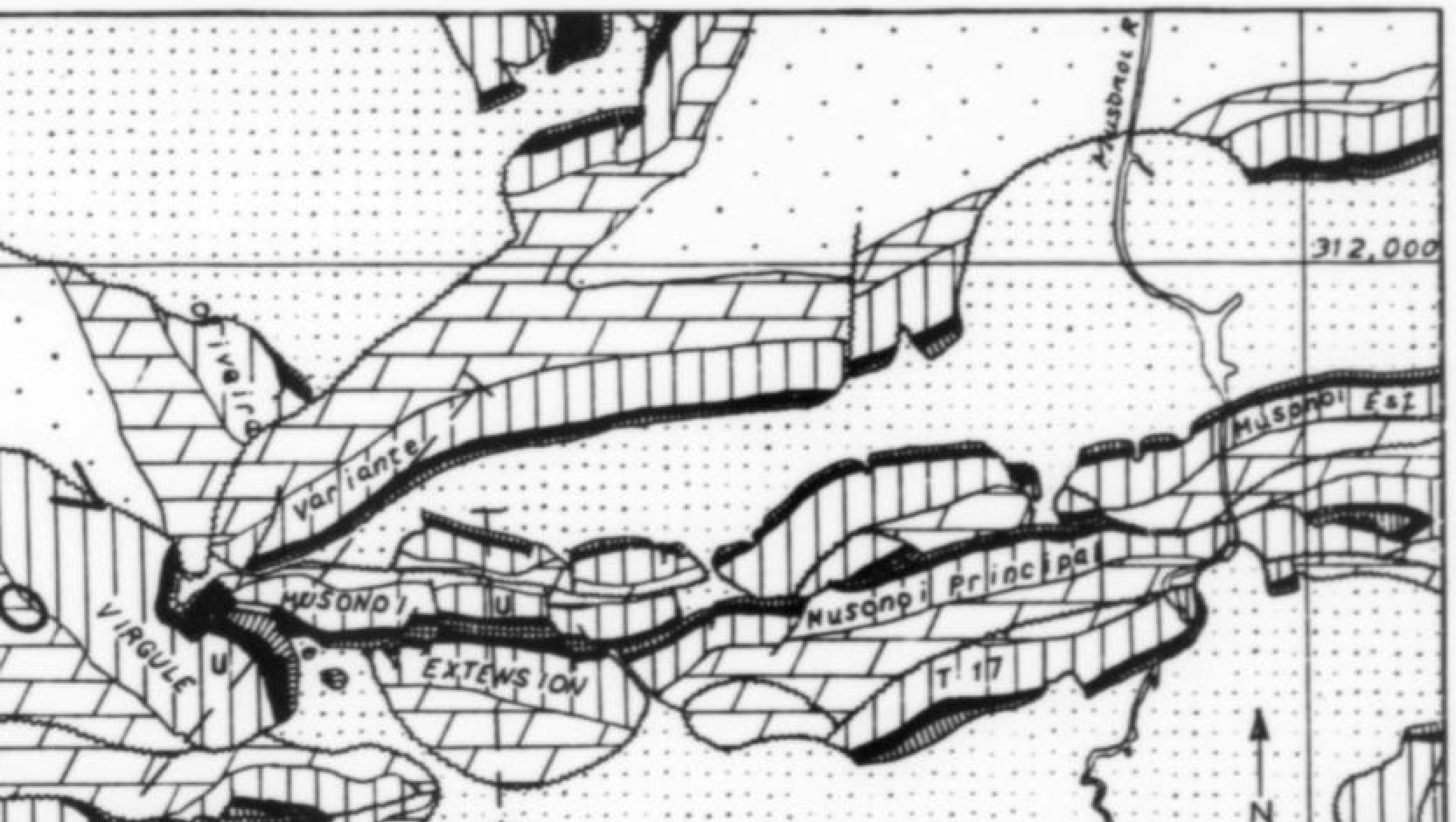

A. P. François

of the Kamoto and Musonoi
çois, 1987) (center portion
pe—see Fig. 8).

A new extension of the Kamoto mine, the KOV deposit, has recently yielded another rich association of secondary minerals, especially roubaulite and zeunerite. (The name "KOV" is an anagram for Kolwezi, Oliveira, Virgule.)

MINERALS

Because only the Shinkolobwe uranium orebody has been extensively exploited, most of the knowledge of Shaba's uranium mineralization is based on studies there. The descriptions given below, unless stated otherwise, refer to minerals from Shinkolobwe.

Only the more important species are described here. The full lists of minerals known from the Shinkolobwe, Swambo, Musonoi and Kamoto mines are given in Tables 1, 2, 3 and 4 respectively.

Particularly useful in preparing the following compilation were the works of Derriks and Vaes (1955), Vaes and Guillemin (1958), François (1974), Deliens *et al.* (1981, 1984) and Gecamines (1977).

Primary Minerals

Cattierite CoS_2

Cattierite is a common sulfide at Shinkolobwe, occurring in characteristic brownish gray masses. Rare cubic crystals have been found which are gray when fresh but which tarnish rapidly to a pinkish tobacco-brown color. Crystal size ranges up to 1 cm.

Cattierite is more stable than vaesite, and never occurs with uraninite or vaesite; associations include siegenite, pyrite and chalcopyrite. It has been found only in carbonate rocks, especially magnesite rock and, to a lesser extent, dolomite. In some cases massive veins of cattierite have been partially or wholely replaced by siegenite.

A chemical series to vaesite (NiS_2) exists, and nickel-rich cattierites have been found commonly in the massive ore at Shinkolobwe. The nickel content is typically 3–4% but may reach 15% in extreme cases (Derriks and Vaes, 1955).

Chalcopyrite $CuFeS_2$

Chalcopyrite and, to a lesser extent, bornite (Cu_5FeS_4) occur with vaesite in the uranium-bearing zone, but never with cattierite (at least in direct association, although there may have been chalcopyrite in the dolomitic gangue of the cattierite veins). Bornite has only been identified in polished section and, unlike chalcopyrite, may be totally or partially secondary. The sulfides bravoite, $(Ni,Fe)S_2$, and pentlandite, $(Fe,Ni)_9S_8$, have also been observed only in polished section. Carrollite, $Cu(Co,Ni)_2S_4$, an extremely abundant sulfide in several copper-cobalt orebodies in the Shaba Crescent, is very rare at Shinkolobwe. Molybdenite (MoS_2), on the other hand, is found frequently in dull masses always associated with uraninite at Shinkolobwe.

Digenite Cu_9S_5

Digenite and also covellite (CuS) have been identified in polished sections from the uranium-bearing zone but are nearly always absent in the cattierite zones.

Gold Au

Gold occurs frequently at Shinkolobwe, especially in the selenium-rich zones and in the central, uranium-rich area of the mine as inclusions in uraninite and sulfides. The inclusions take the form of rods, sheets and, more rarely, small octahedral crystals and dendritic aggregates.

It is possible that the gold is epigenetic or that it has been largely replaced by later minerals. For example, it appears to have developed epigenetically in small vaesite veins, whereas in other veins it has been partially replaced by melonite ($NiTe_2$). Granular platinum and palladium have also been found as inclusions in uraninite.

Linnaeite Co_3S_4

Linnaeite is much subordinate to cattierite, and has been observed only in polished sections.

Monazite-(La) $(La,Ce,Nd)PO_4$

Veins and lodes of monazite-(La) have been found, as honey-yellow micrograins sometimes but not always associated with uraninite. Small veins of monazite-(La) sometimes penetrate or surround uraninite crystals.

Oosterboschite $(Pd,Cu)_7Se_5$

The Musonoi mine is the type locality for oosterboschite (Johan *et al.*, 1970). It has been found only very rarely as grains up to 0.4 mm in size, polysynthetically twinned, and associated with trogtalite, digenite and covellite.

Polydymite Ni_3S_4

Polydymite, unlike vaesite, is entirely stable but very rare. It occurs as beautiful, brilliantly lustrous, silver-gray octahedrons to more than 1 cm in size. Some crystals have been dulled by alteration. Polydymite crystals have been found in only a few vugs, in dolomite located outside the uranium-bearing zone, particularly at shaft landings on the 250-meter level.

Pyrite FeS_2

Pyrite occurs more or less throughout the areas of primary sulfide mineralization, sometimes as lodes, alone or with vaesite or cattierite. Well formed crystals have not been observed.

Siegenite $(Ni,Co)_3S_4$

Siegenite is found rather frequently at Shinkolobwe, as gray masses typically associated with (and replacing) vaesite and, more rarely, with cattierite. Brilliantly lustrous, stable, gray, octahedral crystals to 1 cm occur rarely in vugs.

A selenium-rich siegenite, containing up to 11% Se substituting for sulfur, has also been reported from Shinkolobwe (Derriks and Vaes, 1955).

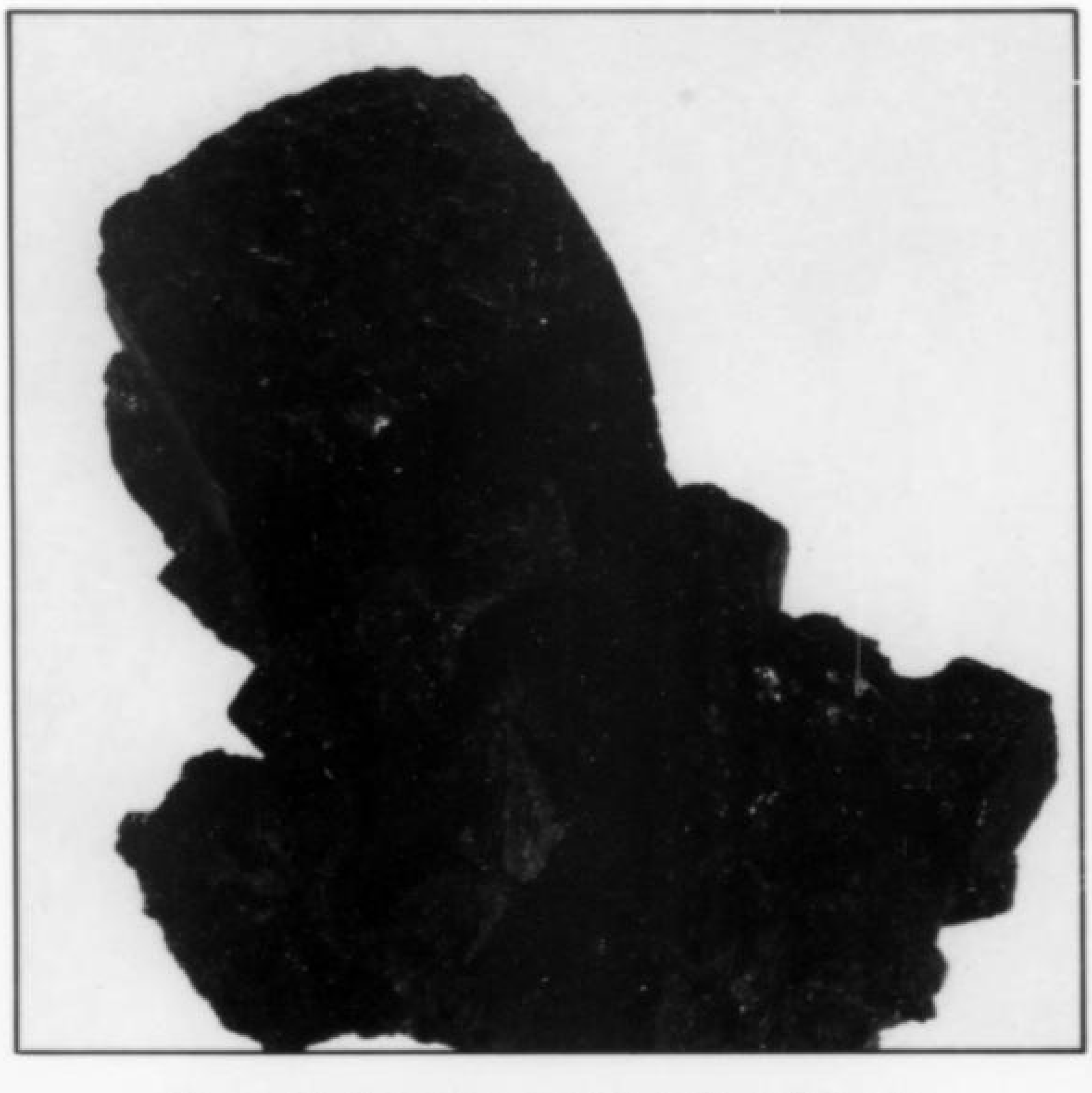

***Figure 11.* Uraninite crystals to 3 cm from the Shinkolobwe mine. Sorbonne collection; Bariand photo.**

Uraninite UO_2

The primary uranium mineralization is limited exclusively to uraninite. This is crystalline uraninite; the colloform "pitchbende" variety is unknown in the Shaba Crescent.

Most of the uraninite has suffered some further oxidation and is no longer stoichiometric UO_2. Additional oxygen plus decay products such as Pb have reduced the uranium content from 88% to about 77%. The composition of "pure" Shinkolobwe uraninite was determined by Davis (1926) to be as follows: UO_2 37.52%, UO_3 52.77%, PbO 7.02%, He 0.159%, N 0.076%, Ce_2O_3 0.22%, ZrO_2 0.14%, $(Y,Er)_2O_3$ 0.35%, and $(La,Dy)_2O_3$ 0.153%, for a total of 98.408%. No thorium was found in the uraninite.

Uraninite crystals occur frequently in vugs and open fissures in the veins and in the surrounding country rock. Forms include the cube, in some cases modified by the octahedron, tetrahexahedron and dodecahedron. Luster varies from bright to dull. Crystal size is typically 5 mm to 2 cm. Crystals sometimes occur grouped on a matrix of massive uraninite; these specimens contain the largest crystals, up to 4 cm on an edge (Derriks and Vaes, 1955).

Euhedral uraninite crystals have been found included in crystals of monazite, vaesite, siegenite, calcite and dolomite (but never cattierite).

Penetration twins of uraninite are common.

Vaesite NiS_2

Vaesite is the main nickel-bearing sulfide at Shinkolobwe and Kasompi. It occurs as black cleavable masses and as rare octahedral crystals measuring up to 1 cm in size. Vaesite is unstable in a humid environment, and collected samples will eventually disintegrate.

When fresh, vaesite crystals are black and brilliantly lustrous. Cleavage fragments of the massive ore are lustrous as well, but become dull and gray after several months.

Vaesite was found associated with uraninite and also in distant parts of the mine, outside the central uranium zone, most often in massive veins or scattered through the adjacent carbonate wall rocks. Associations commonly include pyrite, chalcopyrite, digenite, covellite and bornite.

A chemical series to cattierite (CoS_2) exists, and cobalt-rich vaesites have been found commonly in the massive ore at Shinkolobwe. Most vaesite contains up to 3.5% cobalt, but samples with up to 12.5% cobalt have been found (Derriks and Vaes, 1955). Vaesite and cattierite have never been found together in a single vein. It should be noted that nickel sulfides seem to show a much greater affinity for uranium than do cobalt sulfides.

A selenium-rich vaesite, containing up to 19% Se substituting for sulfur, has also been reported from Shinkolobwe (Derriks and Vaes, 1955).

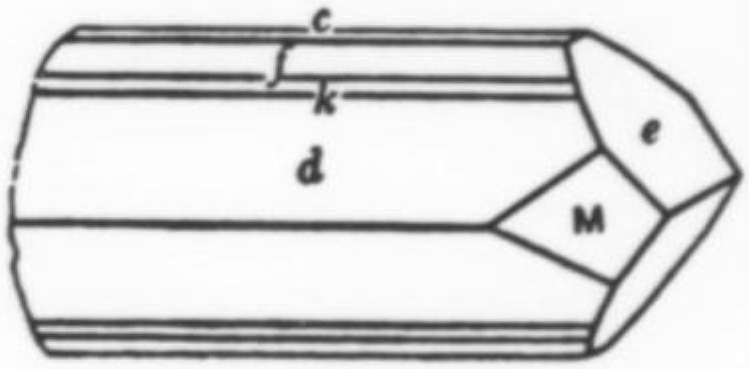

Figure 13. **Crystal drawing of becquerelite from Katanga (Palache *et al.*, 1944).**

Secondary Uranium Minerals

Becquerelite $Ca(UO_2)_6O_4(OH)_6 \cdot 8H_2O$

Becquerelite is among the first alteration products to form from uraninite. It occurs in three principal habits: elongated, beautifully terminated prisms to 2 cm; short, thick, tabular crystals; and acicular crystals to 2.5 cm. Crystals are transparent to translucent and amber-yellow in color. Associations include studtite, schoepite, billietite, curite, fourmarierite, wölsendorfite and sharpite.

Shinkolobwe is the type locality for becquerelite (Schoep, 1922c).

Bijvoetite-(Y) $(Y,Dy)_2(UO_2)_4(CO_3)_4(OH)_6 \cdot 11H_2O$

Bijvoetite-(Y) is an uranyl rare earth carbonate; the rare earths, in descending order, are yttrium, dysprosium, gadolinium and terbium.

Figure 12. **Becquerelite crystals to 5 mm, with uranophane and billietite, from the Shinkolobwe mine. Sorbonne collection; Bariand photo.**

***Figure 14.* Bijvoetite-(Y) crystals from Shinkolobwe. Tervuren Museum collection; photo by G. Comblain.**

The mineral occurs in very beautiful, tabular, transparent to translucent, sulfur-yellow crystals to about 1 mm in size. There is a prominent cleavage parallel to the plane of the tablets (001). Although similar in appearance to other secondary uranium minerals, it can be distinguished by its strong effervescence in hydrochloric acid. It is not fluorescent. Associations include lepersonnite, sklodowskite, uranophane, rutherfordine, becquerelite and curite.

Shinkolobwe is the type locality for bijvoetite-(Y) (Deliens and Piret, 1982).

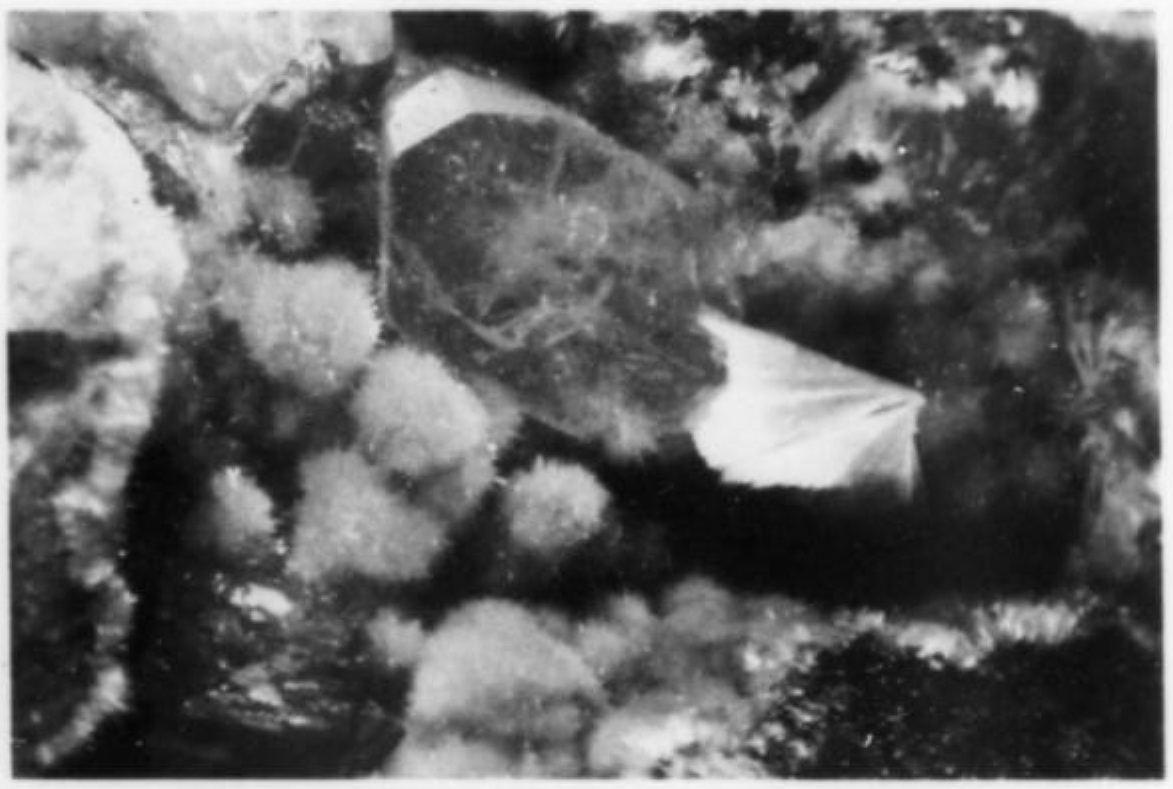

***Figure 15.* Billietite crystal, 2 mm, with white rutherfordine and red wölsendorfite on yellow uranophane from Shinkolobwe.**

Billietite $Ba(UO_2)_6O_4(OH)_6 \cdot 8H_2O$

Billietite is an early alteration product of uraninite. Two habits are known: acicular tufts, and short prismatic crystals showing {010}, {210}, {011} and {201}, with a prominent {001} cleavage. Twins on (111) and (110) are known, showing a pseudohexagonal aspect. Crystals range up to 3 mm in size.

Billietite is isostructural with becquerelite, and has the same amber-yellow color. It is transparent to translucent, forming thin crusts of small crystals, and solidly filling cracks in uraninite. Common associations include studtite, schoepite, becquerelite, masuyite, wölsendorfite, rutherfordine, soddyite and uranophane.

Shinkolobwe is the type locality for billietite (Vaes, 1947).

WEW

***Figure 16.* Cuprosklodowskite vug 5 cm across, from the Musonoi mine. Wayne and Dona Leicht collection.**

Cuprosklodowskite $Cu(UO_2)_2(SiO_3 \cdot OH)_2 \cdot 6H_2O$

Cuprosklodowskite occurs as beautiful apple-green to emerald-green, olive-green and pale green acicular crystals up to about 1 cm long. The needles occur thickly lining voids in massive secondary uranium minerals. Associations include vandenbrandeite and kasolite, sometimes with malachite and rarely becquerelite and soddyite.

Kalongwe, Shaba, is the type locality for cuprosklodowskite (Vaes, 1933), but it has also been found at many other deposits including Kambove, Kasompi, Kolwezi, Luiswishi and Musonoi (Deliens *et al.*, 1981). The specimens from Musonoi are probably the world's finest.

Curienite $Pb(UO_2)_2V_2O_8 \cdot 5H_2O$

Curienite has been found in a single vein at Shinkolobwe as very small, flat, diamond-shaped crystals having an orange-brown color (in contrast to material from the type locality at Mounana, Gabon, which is canary-yellow). Associations include metatorbernite and dumontite (Deliens *et al.*, 1981).

Curite $Pb_2U_5O_{17} \cdot 4H_2O$

Curite is among the earliest alteration minerals to form at Shinkolobwe, and is also one of the most abundant as massive, orange-colored material. It also occurs as fine acicular crystals with an adamantine luster and vermilion-red to orange-red color, transparent to translucent and measuring up to 5 mm in length. Partial or complete pseudomorphs of curite after uraninite are well known. The mineral is sometimes colored black by included cobalt oxides. Associations include becquerelite, billietite, schoepite, fourmarierite, wölsendorfite and others. Shinkolobwe is the type locality for curite (Schoep, 1921a), named after Pierre Curie. It also occurs as Luiswishi, Kalongwe, Kolwezi, Musonoi and Swambo.

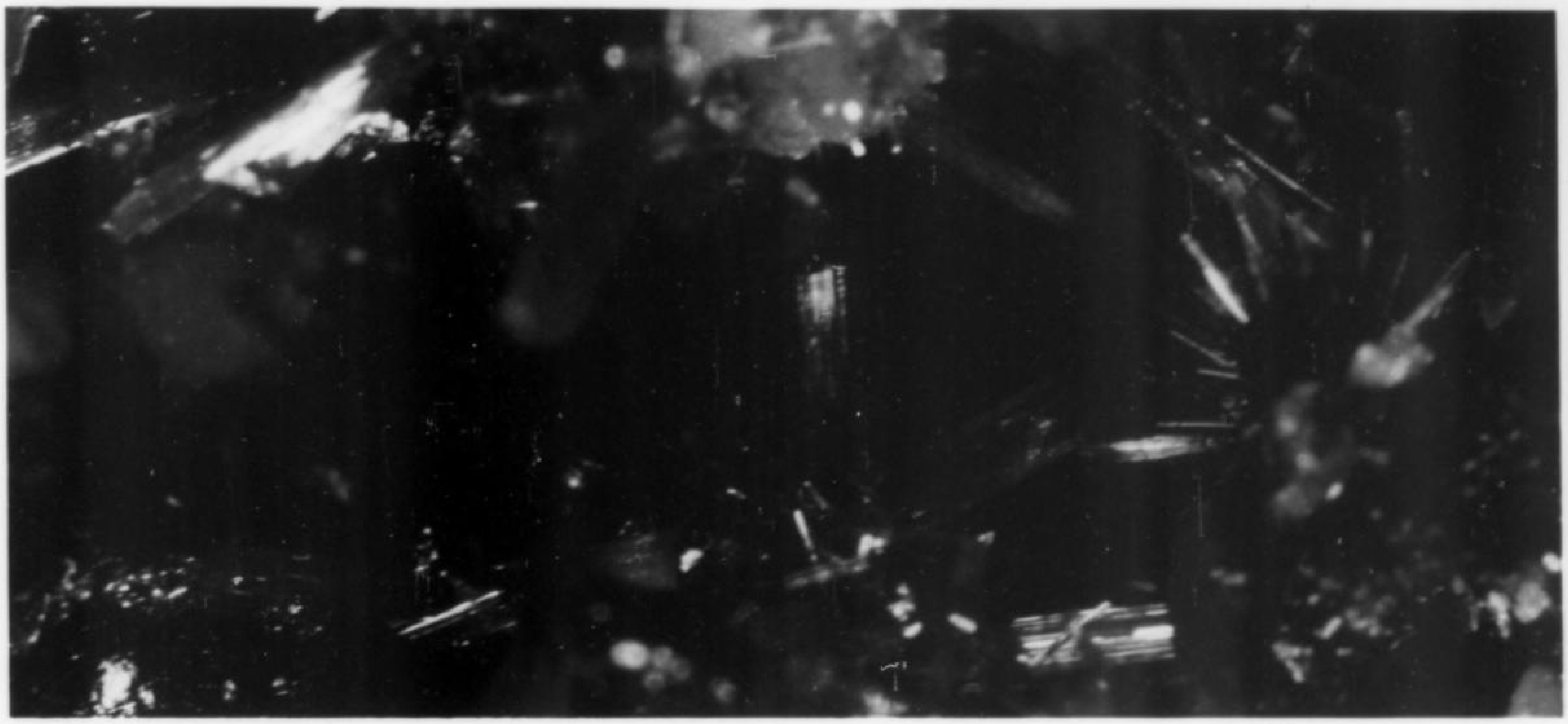

Figure 17. Curite crystals to 2 mm, from the Shinkolobwe mine. Sorbonne collection; Bariand photo.

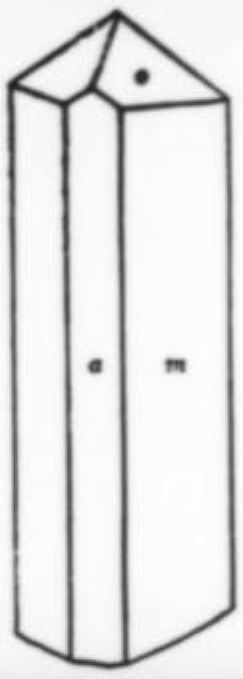

Figure 18. Crystal drawing of curite from Katanga (Palache _et al._, 1944).

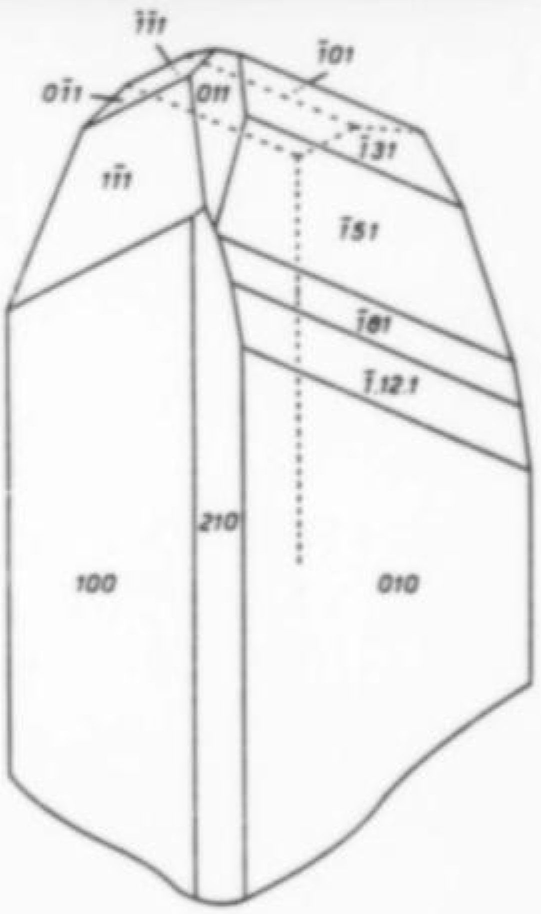

Figure 20. Crystal drawing of demesmaekerite from the Musonoi mine (Cesbron _et al._, 1965).

Figure 19. Demesmaekerite crystals to 2 mm from the Musonoi mine. Tervuren Museum collection; photo by G. Comblain.

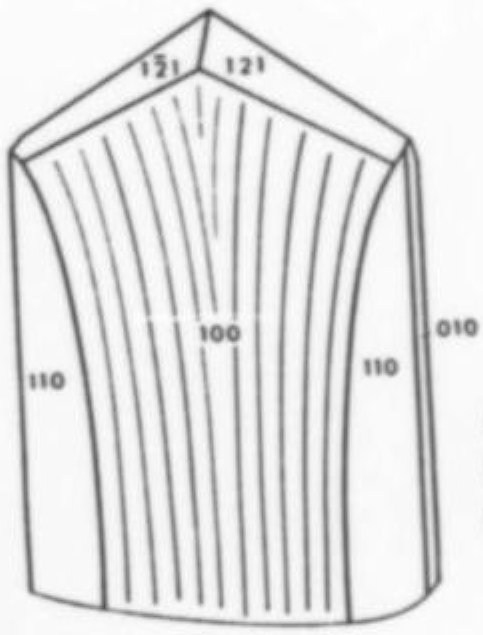

Figure 21. Crystal drawing of derriksite from the Musonoi mine (Cesbron _et al._, 1971).

Demesmaekerite $Pb_2Cu_5(UO_2)_2(SeO_3)_6(OH)_6 \cdot 2H_2O$

The Musonoi mine is the type locality for demesmaekerite (Cesbron _et al._, 1965). The crystals are a light bottle-green in color, sometimes slightly brownish, and may be transparent when fresh but dehydrate to an opaque, pale olive-green or greenish yellow color. Crystals are lamellar to prismatic, commonly groups in fans and diverging sprays, but also as isolated individuals to 1 cm. Associations include malachite, chalcomenite, derriksite, marthozite and guilleminite.

Derriksite $Cu_4(UO_2)(SeO_3)_2(OH)_6$

The Musonoi mine is the type locality for derriksite (Cesbron _et al._, 1971). Crystals are generally small and prismatic, often convex, sometimes reaching a millimeter or so in size. Color ranges from pale green to malachite-green. Crystals are often found growing directly on selenium-rich digenite, along with other uranoselenides. Associations include malachite, chalcomenite, demesmaekerite, marthozite and guilleminite.

Dewindtite $Pb_{2-3}(UO_2)_{4-6}(PO_4)_{3-4}(OH)_{3-6}\cdot 7\text{–}10H_2O$ (?)
and **Renardite** $Pb(UO_2)_4(PO_4)_2(OH)_4\cdot 7H_2O$ (?)

These mineral species require some re-examination. They have been shown to be isostructural, but their formulas cannot be reconciled on this basis (Frondel and Cuttitta, 1954). It is possible that they are the same species (Fleischer, 1987).

Generally elongated and flattened prisms to 2 mm, as well as acicular and tabular crystals of what has tentatively been identified as renardite have been found at Shinkolobwe. The crystals are transparent and often grouped in sub-parallel or radiating clusters. Color ranges from pale yellow to lemon-yellow. The principal associations are metatorbernite and, to a lesser extent, phosphuranylite and parsonsite.

Shinkolobwe is the type locality for renardite (Schoep, 1928); it also occurs at Swambo, with kasolite and metatorbernite (Deliens *et al.*, 1981). Dewindtite was originally reported from Kasolo, Katanga (Schoep, 1922a, 1925), in association with torbernite and other secondary uranium minerals. It was described as microscopic rectangular tablets flattened on {100}, striated, and canary-yellow in color.

Dumontite $Pb_2(UO_2)_3(PO_4)_2O_2\cdot 5H_2O$

Dumontite is among the rarest of the secondary uranium minerals at Shinkolobwe. Crystals are flat to elongated [001] prismatic and acicular with striations parallel to their length. Color ranges from pale yellow to golden yellow. Metatorbernite is sometimes associated.

Shinkolobwe is the type locality for dumontite (Schoep, 1924b).

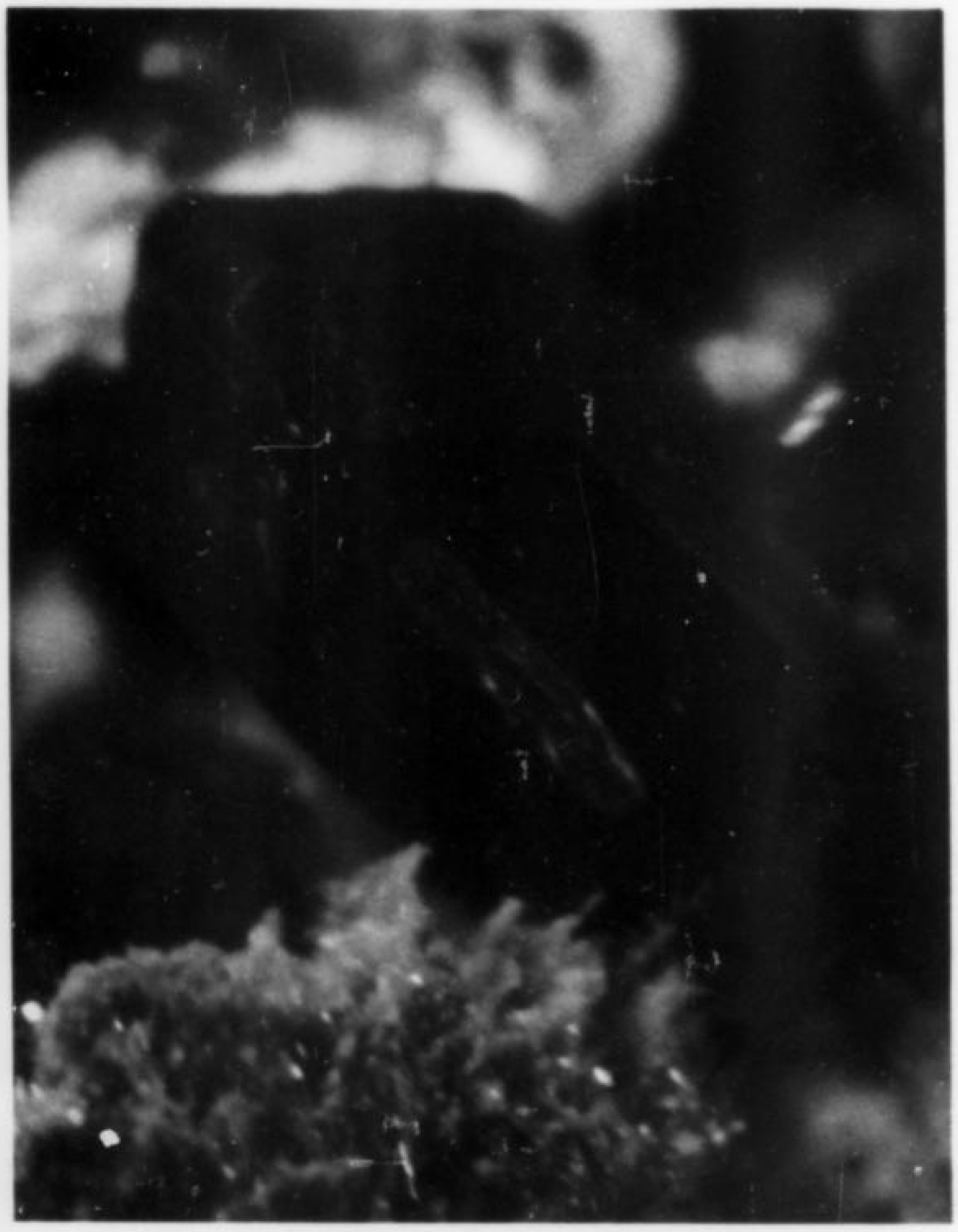

Figure 22. **Fourmarierite crystal, 1.5 mm, on vandendreisscheite from Shinkolobwe.**

Fourmarierite $PbU_4O_{13}\cdot 6H_2O$

Fourmarierite occurs in three principal habits: flattened, tabular crystals to 2 mm having an elongated hexagonal shape and showing the forms {100}, {110} and {111}; elongated prisms; and clumps of acicular crystals resembling sea urchins. Color ranges from bright red and carmine-red to red-orange and orange-yellow. The mineral is generally transparent to translucent and is frequently twinned. It occurs in a wide range of associations with minerals including studtite, billietite, becquerelite, curite, vandendriesscheite, rutherfordine, torbernite, metatorbernite, uranophane and kasolite.

Shinkolobwe is the type locality for fourmarieite (Buttgenbach, 1924).

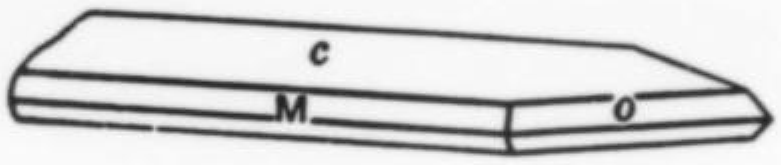

Figure 24. **Crystal drawing of ianthinite from the Shinkolobwe mine (Palache *et al.*, 1944).**

Francevillite $(Ba,Pb)(UO_2)_2V_2O_8\cdot 5H_2O$

Francevillite occurs at Musonoi as yellow coatings, often mixed with tyuyamunite. The crystals are not well formed.

Françoisite-(Nd) $3UO_3\cdot \frac{1}{2}(REE)_2O_3\cdot P_2O_5\cdot 6.5H_2O$

Françoisite-(Nd) forms aggregates of yellow micaceous tablets. The maximum length in the elongation is 0.3 mm. It is found together with kamotoite-(Y), shabaite-(Nd) and uranophane on uraninite matrix. It differs from the other secondary rare earth minerals of the deposit in the lack of reaction with hydrochloric acid. The type locality of françoisite-(Nd) is the Kamoto-East mine (Piret, Deliens and Piret-Meunier, 1988).

Guilleminite $Ba(UO_2)_3(SeO_3)_2(OH)_4\cdot 3H_2O$

Guilleminite has been found very rarely at Shinkolobwe, as crystals and more often as bright yellow, radially fibrous nodules associated with masuyite and rutherfordine. The type locality, however, is the Musonoi mine where it is more abundant, and is accompanied by malachite, wulfenite, uranophane, kasolite, vandenbrandeite, cuprosklodowskite, and metatorbernite, as well as chalcomenite, marthozite, derriksite and demesmaekerite (Deliens *et al.*, 1981). At Musonoi guilleminite occurs as yellow, opaque to translucent (rarely transparent) prisms, needles and tablets to 5 mm in size.

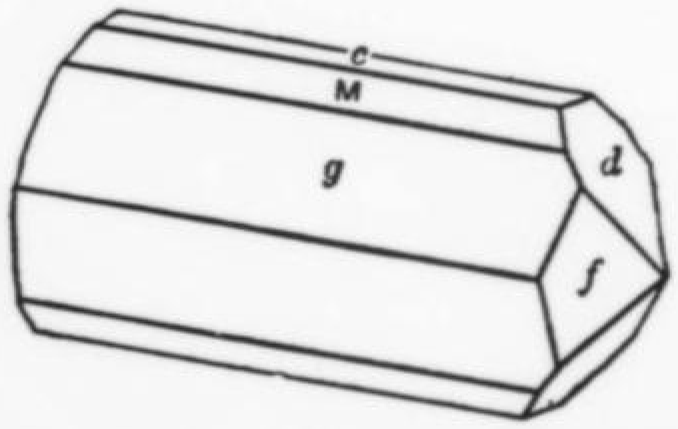

Figure 23. **Crystal drawing of fourmarierite from Katanga (Palache *et al.*, 1944).**

Ianthinite $UO_2\cdot 5UO_3\cdot 10H_2O$

Ianthinite is the first alteration product to form from uraninite, as the result of a reducing aqueous environment. It occurs in uraninite relicts in the alteration zone, also in the transition zone, and possibly as far as the country rock boundary. Crystals occur in tight vugs where groundwater circulation was very limited.

Crystals are always purple in color, acicular [010] in habit, as tangled nests and radially fibrous rosettes. The maximum crystal size is about 2 mm. Forms identified include {001}, {101}, {130}, {103} and {011}. Associations, where present, include schoepite, billietite, becquerelite and fourmarierite.

Ianthinite is an unstable mineral, altering on exposure to light and air, to pseudomorphs of schoepite after ianthinite (sometimes referred to as "epi-ianthinite").

Shinkolobwe is the type locality for ianthinite (Schoep, 1926).

Iriginite $(UO_2)Mo_2O_7\cdot 3H_2O$

Iriginite occurs with molybdenite at Shinkolobwe, as minute, bright yellow crystals and bronze to yellow platelets and powder resulting from the alteration of umohoite.

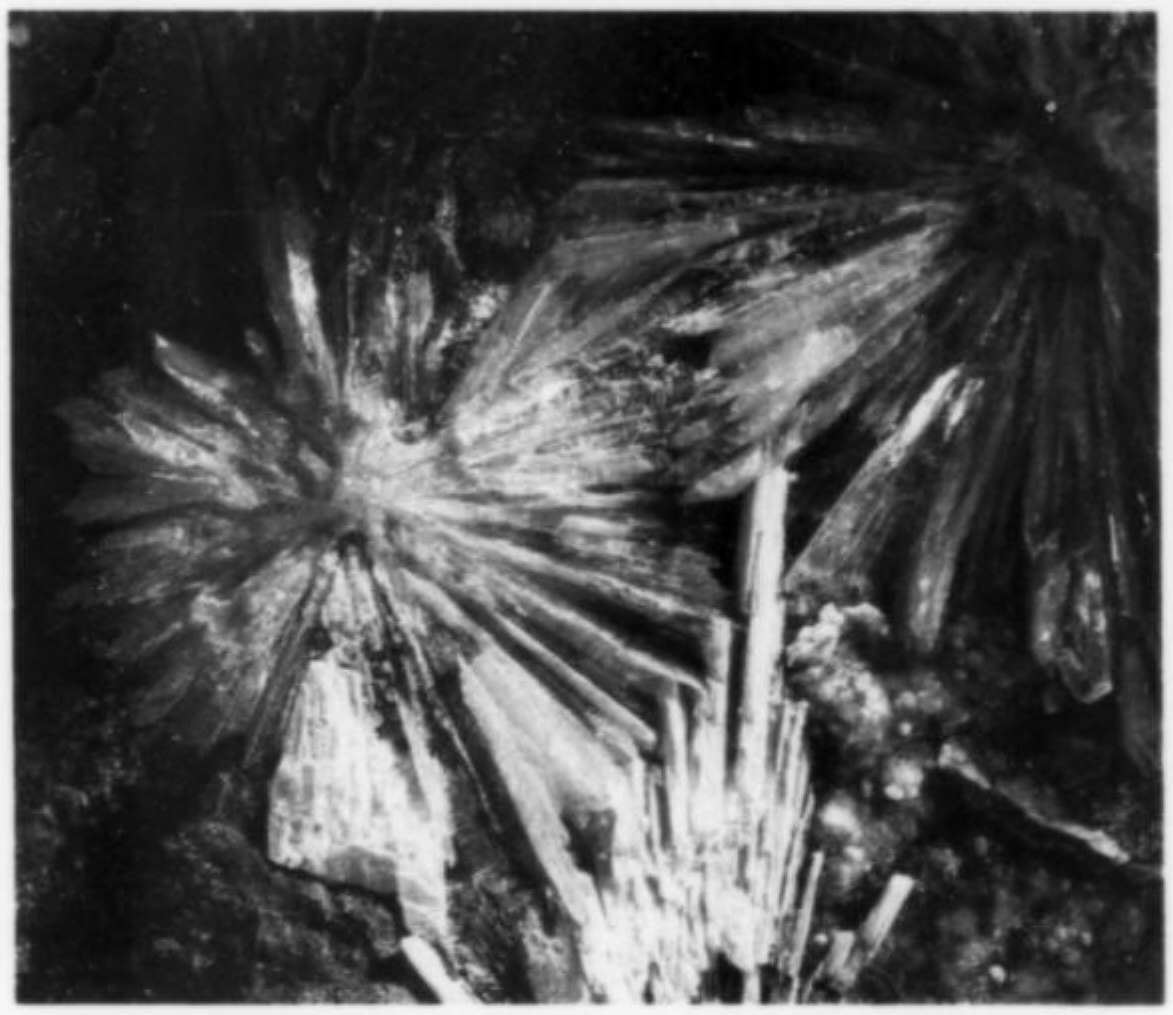

Figure 25. **Kamotoite-(Y) sprays from the Kamoto-East mine; the field of view is about 1 cm across. Sorbonne collection; Bariand photo.**

Kamotoite-(Y) $4UO_2\cdot(REE)_2O_3\cdot 3CO_2\cdot 14.5H_2O$

The Kamoto-East mine is the type locality for kamotoite-(Y) (Deliens and Piret, 1986). It is relatively abundant in the deposit as crusts of elongated bright yellow tablets, on uraninite matrix. The tablets, which can reach 1 cm, are commonly gathered in clusters. The mineral is commonly associated with shabaite-(Nd) and uranophane, less frequently with the rare uranyl and rare earth phosphate françoisite-(Nd).

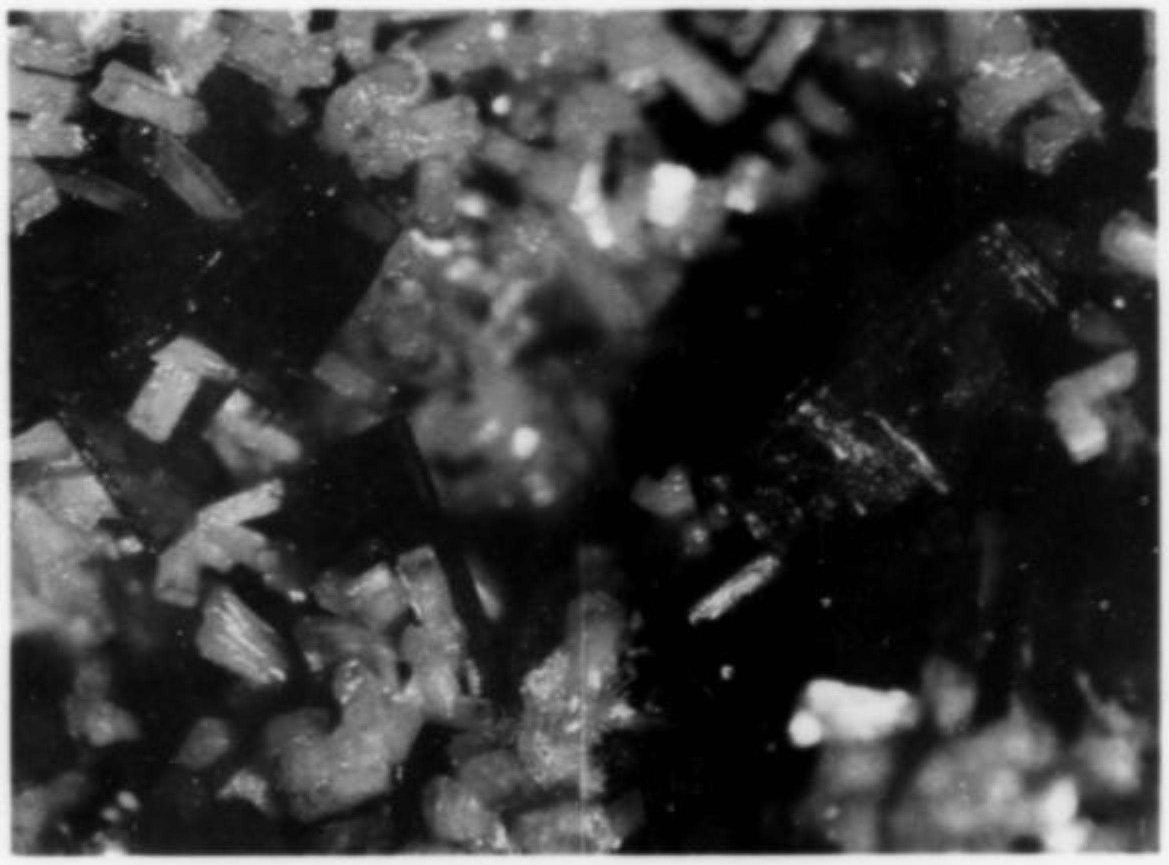

Figure 26. **Yellow kasolite crystals to 1 mm, with torbernite, from the Musonoi mine. Collection and photo: W. Pinch.**

Kasolite $Pb(UO_2)SiO_4\cdot H_2O$

Kasolite is abundant in the upper portion of the oxidation zone at Shinkolobwe, and extends well beyond the deposit in small openings in the country rock. It forms elongated prisms rarely exceeding 5 mm, grouped in sheaves and fan-shaped aggregates. A few isolated crystals are double terminated. The fine rosettes so typical of Shinkolobwe occur mostly in country rock. Kasolite is also found as fibrous and massive material, and as pseudomorphs after quartz. Color ranges from ochre-yellow to orange and brown; crystals are generally translucent to opaque, rarely transparent. Associations include schoepite, vandenbrandeite, curite, torbernite-metatorbernite, renardite, soddyite and uranophane.

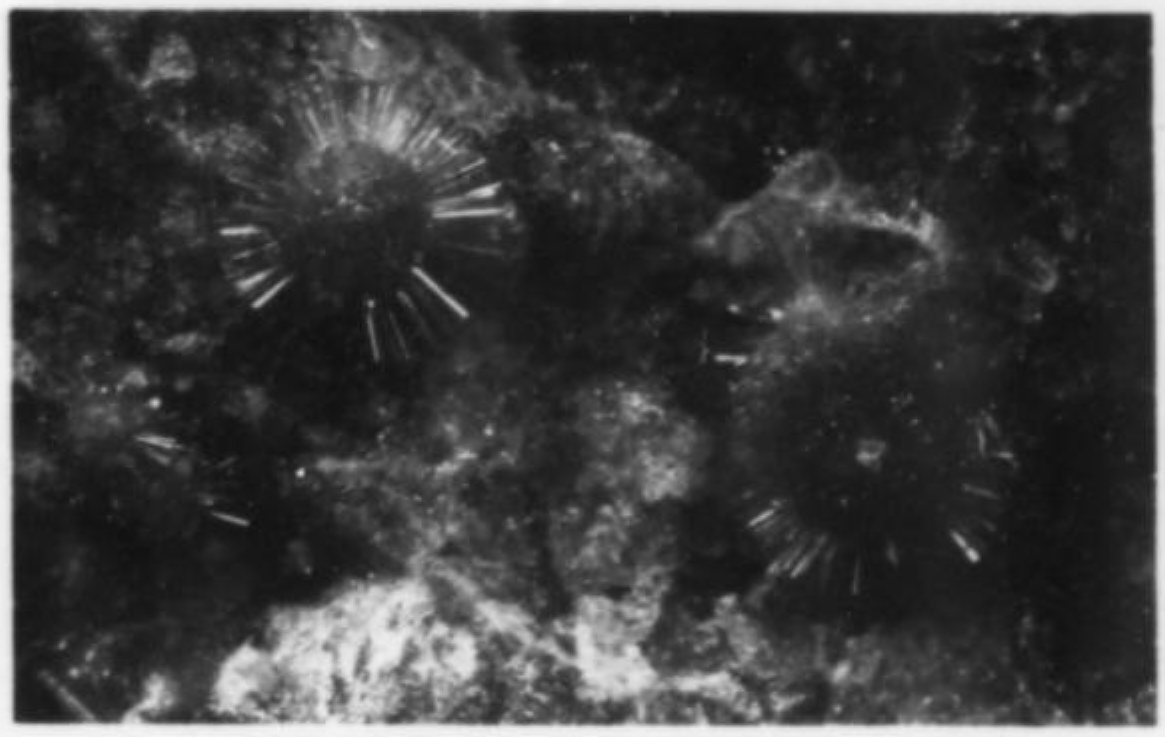

Figure 27. **Kasolite rosettes to 3 mm from the Swambo mine. Sorbonne collection; Bariand photo.**

Shinkolobwe is the type locality for kasolite (Schoep, 1921b), but it has also been reported from Menda, Swambo, Luiswishi, Kambove, Kalongwe and Musonoi (Deliens *et al.*, 1981).

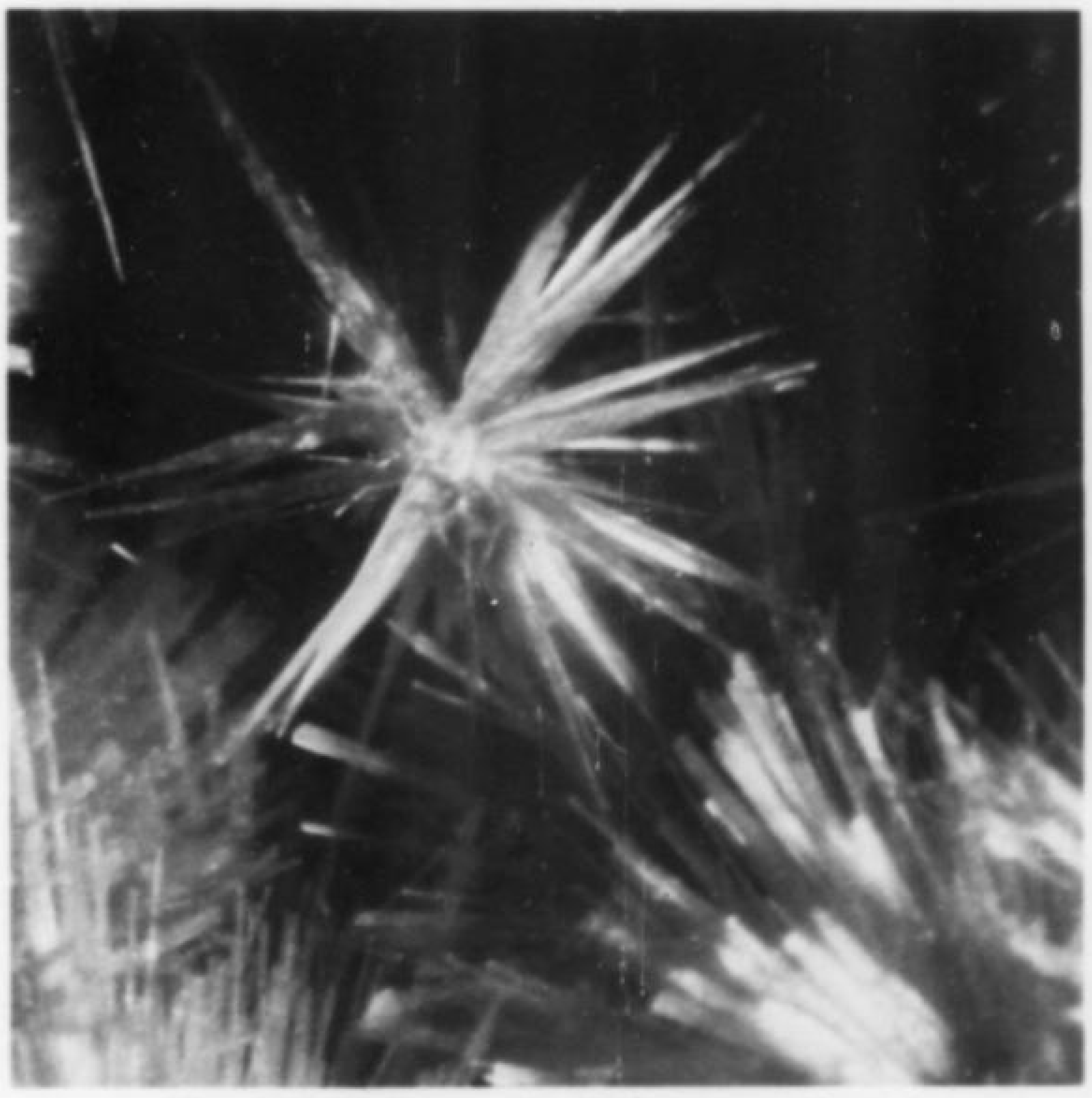

Figure 28. **Leppersonite-(Gd) sprays, about 1 mm, from Shinkolobwe. Tervuren Museum specimen; photo by G. Comblain.**

Lepersonnite-(Gd) $CaO\cdot(Gd,Dy)_2O_3\cdot 24UO_3\cdot 8CO_2\cdot 4SiO_2\cdot 60H_2O$

Lepersonnite-(Gd), like bijvoetite-(Y), is a uranyl rare earth carbonate containing, in descending order, gadolinium, dysprosium, yttrium and terbium. The mineral occurs as bright yellow, acicular, transparent to translucent crystals in rosettes and "sea-urchin" bunches. It is not fluorescent. Many samples in collections labeled "studtite" are probably lepersonnite-(Gd), and can be distinguished

Figure 29. **Masuyite crystals to 1 mm on uranophane from the Shinkolobwe mine. Sorbonne collection; Bariand photo.**

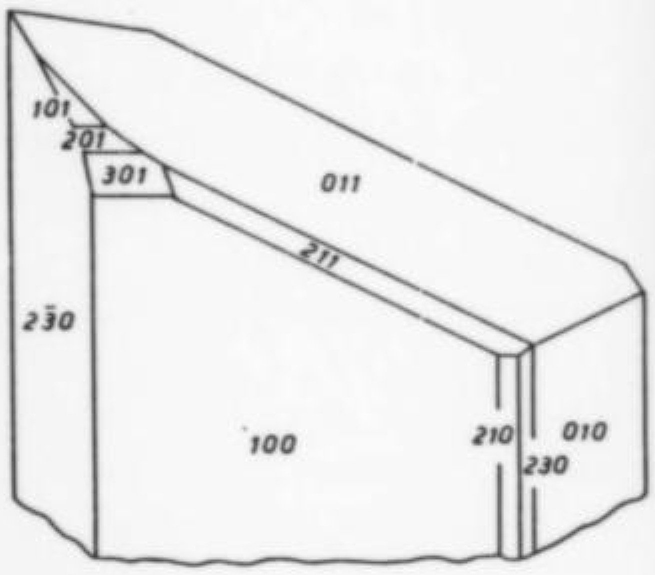

Figure 30. **Crystal drawing of marthozite from the Musonoi mine (Cesbron *et al.*, 1969).**

Figure 31.**Marthozite crystals, about 2 mm, from Musonoi. Tervuren Museum collection; photo by G. Comblain.**

by effervescence in hydrochloric acid. Lepersonnite is abundant at Shinkolobwe, where it is associated with uraninite, uranophane, sklodowskite, oursinite and many others.

Shinkolobwe is the type locality for lepersonnite-(Gd) (Deliens and Piret, 1982).

Liebigite $Ca_2UO_2(CO_3)_3 \cdot 11H_2O$

Liebigite occurs at Shinkolobwe associated with wyartite in yellow and black rosettes, with schoepite, wölsendorfite and wulfenite on uraninite matrix. The uraninite crystals have been partially replaced pseudomorphically by uranophane. Liebigite forms microcrystalline crusts of micaceous tablets. The color is yellowish white with a greasy luster. It fluoresces bluish green under shortwave and longwave ultraviolet light.

Only one occurrence is reported in the deposit (Deliens, 1985).

Marthozite $Cu(UO_2)_3(SeO_3)_3(OH)_2 \cdot 7H_2O$

The Musonoi mine is the type locality for marthozite (Cesbron *et al.*, 1969). The mineral occurs as prismatic crystals to 3 mm and as pyramidal-lamellar crystals tending toward a triangular shape, up to 1 cm across. Fresh crystals are transparent, but they become opaque upon dehydration. Color ranges from yellowish green to greenish brown. Associations include malachite, derriksite, chalcomenite, demesmaekerite and guilleminite.

Masuyite $Pb_3U_8^{+6}O_{27}\cdot 10H_2O$

Masuyite forms tiny, short, flattened, prismatic crystals, and pseudohexagonal flakes, small rod-shaped crystals, and fibrous bunches and radiating spherules. The radiating groups sometimes occur as roughly circular planar sheets with serrated edges. Color ranges from carmine-red to orange and yellow-orange. Twins consisting of two, three and four individuals are common. Crystals are transparent to translucent, and occur frequently in association with billietite on a background of uranophane, but also with many of the hydrous uranium oxides, the uranates of Pb, Ba and Ca, rutherfordine and wyartite.

Shinkolobwe is the type locality for masuyite (Vaes, 1947).

Metastudtite $UO_4\cdot 2H_2O$

Metastudtite is the dehydration product of studtite (which has 4 waters). It occurs very rarely as radiating fibrous aggregates, rosettes and tangled, fibrous masses of thin, flexible needles. Color ranges from bright yellow to very pale yellow. Associations include wölsendorfite, masuyite, rutherfordine, uranophane, kasolite, studtite and soddyite.

Shinkolobwe is the type locality for metastudtite (Deliens and Piret, 1983).

Metatorbernite (see Torbernite)

Metatyuyamunite $Ca(UO_2)_2V_2O_8\cdot 3H_2O$

Superb metatyuyamunite crystals have recently been found at the Mashamba-West mine near Musonoi. This is the first reported occurrence of the mineral in the Shaba Crescent. It occurs as bright yellow to orange, translucent tablets terminated by an asymmetrical point, generally grouped to form sheaves. Associations include malachite and goethite (Deliens *et al.*, 1984).

Oursinite $(Co,Mg)(UO_2)_2Si_2O_7\cdot 6H_2O$

Oursinite occurs as pale yellow to whitish, transparent to translucent, acicular prisms and needles to 1 mm in clusters and rosettes resembling sklodowskite. Associations include sklodowskite, kasolite, soddyite, curite, schoepite, metatorbernite, lepersonnite-(Gd) and bijvoetite-(Y).

Shinkolobwe is the type locality for oursinite (Deliens and Piret, 1983).

Parsonsite $Pb_2(UO_2)(PO_4)_2\cdot 2H_2O$

Elongate prismatic and acicular crystals of parsonsite have been found at Shinkolobwe, as well as massive material. All Shinkolobwe parsonsite is chocolate-brown in color; elsewhere in the world it is yellow to greenish yellow. Crystals, which are quite rare, range from transparent to opaque. Associations include renardite, phosphuranylite, kasolite and metatorbernite.

Shinkolobwe is the type locality for parsonsite (Schoep, 1923)

Phosphuranylite $Ca(UO_2)_3(PO_4)_2\cdot 6H_2O$

Rectangular, lamellar crystals of amber-yellow to golden yellow phosphuranylite occur at Shinkolobwe, mostly as microcrystalline coatings. Associations include renardite, parsonsite, saleeite and metatorbernite.

Phurcalite $Ca_2(UO_2)_3(PO_4)_2(OH)_4\cdot 4H_2O$

Phurcalite has been found rarely to occur at Shinkolobwe, as needles and elongated tablets terminated by dome faces. It is bright yellow and transparent. Associations are limited to black cobalt oxides (Deliens and Piret, 1978).

***Figure 32*. Metatyuyamunite crystals to 3 mm, with green malachite, from the Mashamba-West mine. M. Lohest collection; Bariand photo.**

Protasite $Ba(UO_2)_3(OH)_2 \cdot 3H_2O$

Only a single specimen of protasite is known. The mineral occurs as bright orange, transparent, pseudohexagonal platelets to 0.5 mm in size, flattened on {010} and possessing a good cleavage on {010}. All crystals show sector twinning by a 60° rotation about [010]. Protasite is brittle with a hackly fracture and subadamantine luster. Although it closely resembles fourmarierite, it can be distinguished by its platy habit and twinning striations. Associations include uraninite and uranophane.

Shinkolobwe is the type (and only known) locality for prostasite (Pagoaga *et al.*, 1986).

Renardite (see Dewindtite)

Richetite $PbU_4^{+6}O_{13} \cdot 4H_2O$

Richetite is among the rarest minerals at Shinkolobwe. It forms as flattened, tabular crystals most often made up of superposed thin sheets with parallel or sub-parallel orientation yielding a pseudohexagonal outline. Thin, translucent sheets show a brownish color; thicker crystals are black. Associations include becquerelite, uranophane, primary uraninite, kasolite, rutherfordine, wulfenite, masuyite and wölsendorfite.

Shinkolobwe is the type locality for richetite (Vaes, 1947).

Roubaultite $Cu_2(UO_2)_3(CO_3)_2O_2(OH)_2 \cdot 4H_2O$

Roubaultite occurs as rosettes to about 3 mm in diameter and pale green in color. It is among the rarest uranium minerals at Shinkolobwe. Associations include becquerelite, vandenbrandeite, soddyite, cuprosklodowskite and heterogenite (at least on the basis of the holotype specimen kept at the School of Mines in Paris).

Nice crystals of roubaultite were found in 1987 at Kamoto (KOV). They occur as apple-green prisms and flattened tablets that can reach more than 3 mm.

Shinkolobwe is the type locality for roubaultite (Cesbron *et al.*, 1970).

***Figure 33*. Tan rutherfordine crystals to 1 mm, on yellow uranophane and green cuprosklodowskite, from the Musonoi mine. M. Lohest collection; Bariand photo.**

Rutherfordine $UO_2(CO_3)$

Rutherfordine forms translucent, lamellar to acicular needles, rods, slats, blades, bundles, fans and fibrous aggregates to several millimeters in size. Color ranges from straw-yellow to tobacco-brown and very pale brown. Associations include uranophane, fourmarierite, wölsendorfite, becquerelite, uraninite and cuprosklodowskite.

Rutherfordine has been found at Shinkolobwe and Musonoi.

Saleeite $Mg(UO_2)_2(PO_4)_2 \cdot 10H_2O$

Thick, square tablets of saleeite, in sub-parallel groups and clusters almost always associated with tobernite-metatorbernite are relatively common at Shinkolobwe. Epitaxial intergrowths and mixed crystals are also well known. Crystals are sometimes transparent when fresh but slowly dehydrate and become opaque. The color is pale yellow to greenish yellow. Renardite is sometimes associated.

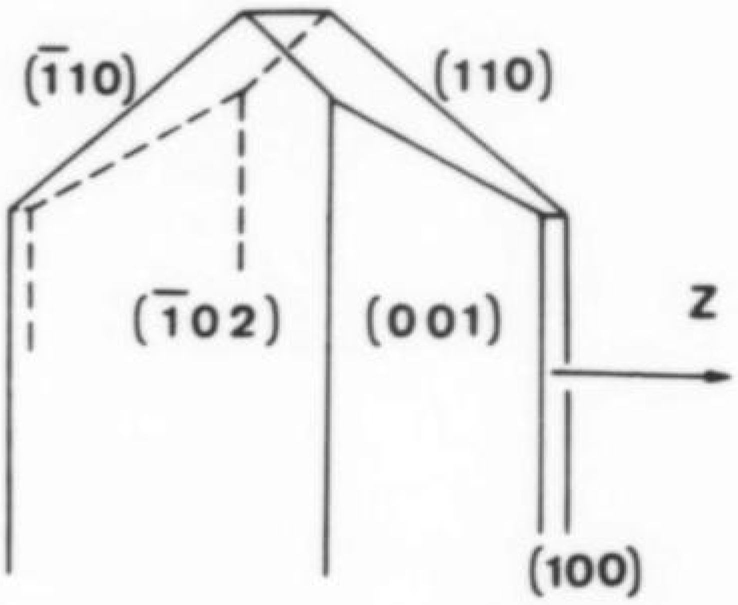

***Figure 34*. Crystal drawing of sayrite from the Shinkolobwe mine (Piret *et al.*, 1983).**

Sayrite $Pb_2(UO_2)_5O_6(OH)_2 \cdot 4H_2O$

Sayrite occurs as prismatic crystals with two-face terminations, transparent to translucent, and red to yellow-orange in color. Crystal size reaches about 0.5 mm. Sayrite has long been confused with masuyite but can be easily distinguished by the interfacial angle of the two terminal faces: 72° for sayrite, 120° for masuyite. Associations include uraninite, becquerelite, richetite and masuyite.

Shinkolobwe is the type locality for sayrite (Piret *et al.*, 1983).

Shabaite-(Nd) $Ca(REE)_2UO_2(CO_3)_4(OH)_2 \cdot 6H_2O$

This uranyl and rare earth carbonate is another new mineral from the Kamoto-East mine. It forms radiating aggregates of micaceous tablets. The color is straw-yellow and the maximum length of the flakes of 0.5 mm. Shabaite-(Nd) is closely associated with kamotoite-(Y) and uranophane, less commonly with françoisite-(Nd) and schuilingite (lead, copper and rare earth carbonate). It is strongly soluble with effervescence in cold hydrochloric acid (Deliens and Piret, 1989).

Schmitterite $(UO_2)TeO_3$

Schmitterite occurs at Shinkolobwe as lemon-yellow rosettes to 2 mm which are composed of radically arranged platelets. It is found with uraninite, siegenite, covellite, chalcocite, pyrite and yellow-orange saleeite (Deliens and Piret, 1976).

Schoepite $UO_3 \cdot 2H_2O$

Schoepite occurs near uraninite as an early alteration product; cubic pseudomorphs after uraninite have been found. The flattened (001), tabular crystals, up to 1 cm in size, are amber-yellow to lemon-yellow and transparent to translucent. Opaque crystals are dehydrated phases sometimes referred to as "paraschoepite" and "metaschoepite." Common crystal forms include {110}, {100}, {210}, {011} and {110}, with a perfect cleavage on {001}. It also forms compact masses filling cracks in uraninite.

In the lower zone of the Shinkolobwe deposit, schoepite sometimes occurs in association with becquerelite on a thin crust of ianthinite. In the upper zone it occurs with curite and soddyite.

Shinkolobwe is the type locality for schoepite (Walker, 1923).

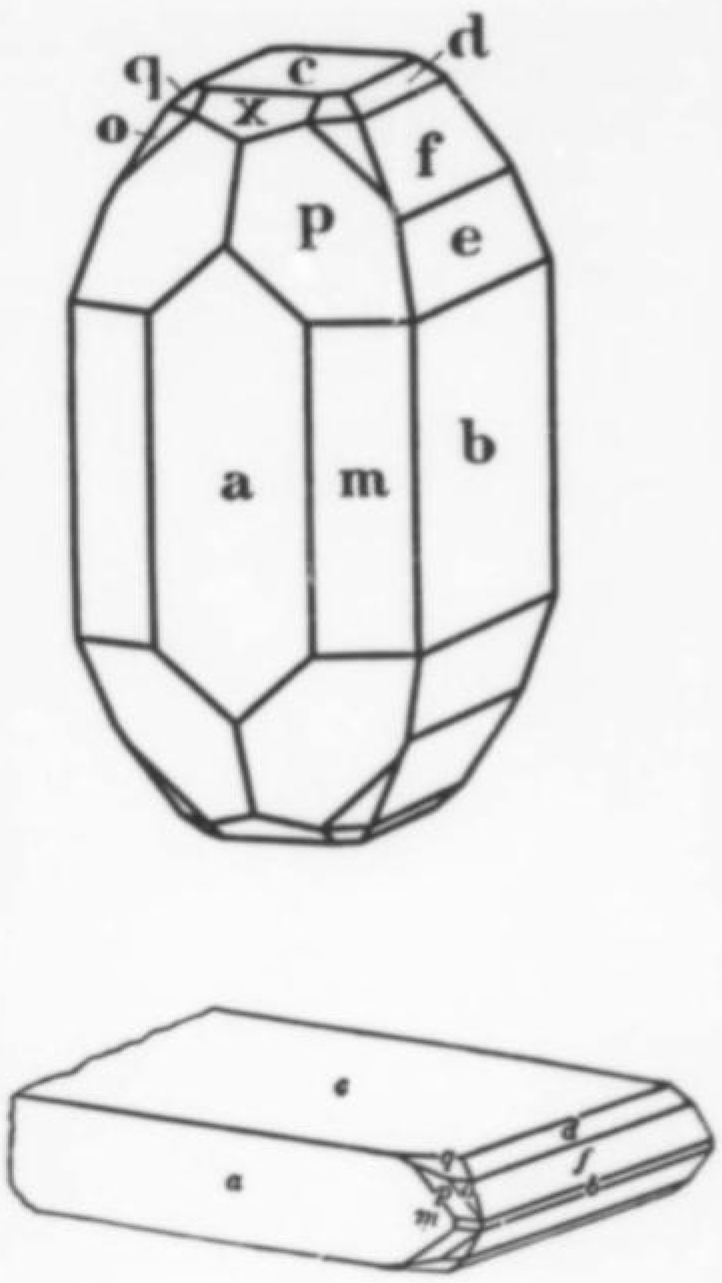

Figure 36. **Crystal drawings of schoepite from (above) the Shinkolobwe mine (Walker, 1923) and (below) Katanga (Palache *et al.*, 1944).**

Figure 37. **Schoepite crystals to 2 mm from the Shinkolobwe mine. Sorbonne collection; Bariand photo.**

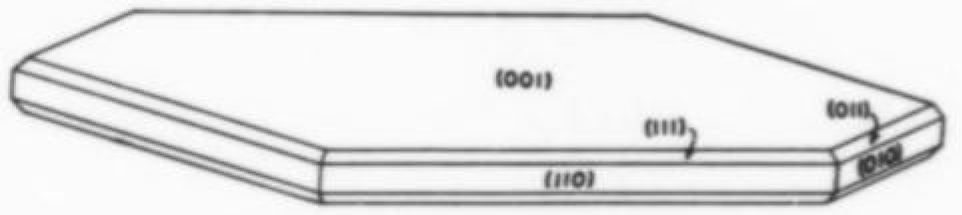

Figure 35. **Crystal drawing of sengierite from Luiswishi (Vaes and Kerr, 1949).**

Sengierite $Cu_2(UO_2)_2V_2O_8 \cdot 6H_2O$

Sengierite has been found at Shinkolobwe as small, tabular, transparent crystals, thin and diamond-shaped in outline, up to about 2 mm in size. Their color ranges from olive-green to yellowish green.

Luiswishi, Shaba, is the type locality for sengierite (Vaes and Kerr, 1949). It occurred there in fissures in talc-chlorite rock of the Mines Series, associated with vandenbrandeite, malachite and chrysocolla. It also occurs at Musonoi, associated with guilleminite, kasolite, malachite, metatorbernite and mottramite. At the Ruwe mine it has been found with metatorbernite.

Sharpite $Ca(UO_2)_6(CO_3)_5(OH)_4 \cdot 6H_2O$

Sharpite is a very rare mineral, found almost always as radially fibrous masses ranging from yellowish green to brownish yellow and pale brown in color. Associations include wölsendorfite, curite, becquerelite and uranophane.

Shinkolobwe is the type locality for sharpite (Melon, 1938).

Sklodowskite $(H_3O)_2Mg(UO_2)_2(SiO_4)_2 \cdot 4H_2O$

Sklodowskite occurs as elongated, acicular crystals rarely exceeding 5 mm in length, occurring as tangled or radiating needles, tufts, rosettes and (rarely) flakes. It occurs in the upper part of the oxidation zone. Color ranges from pale yellow to pale greenish yellow and nearly colorless. The crystals are transparent. It is also found in massive form, particularly as an alteration crust on uraninite.

Shinkolobwe is the type locality for sklodowskite (Schoep, 1924a), named after Marie Sklodowska Curie. Associations there include schoepite, billietite, becquerelite, curite and rutherfordine among others. It is also known to occur at Kalongwe (with cuprosklodowskite and vandenbrandeite), Luiswishi, Musonoi and Swambo.

In 1923 Schoep described what he thought was another new mineral from Shinkolobwe, naming it "chinkolobwite"; it proved later to be sklodowskite.

Soddyite $(UO_2)_2SiO_4 \cdot 2H_2O$

Soddyite occurs at Shinkolobwe as bipyramidal {111} crystals, elongated prismatic crystals, flattened sheets, and fibrous and crystalline masses. Color ranges from amber-yellow in the transparent crystals

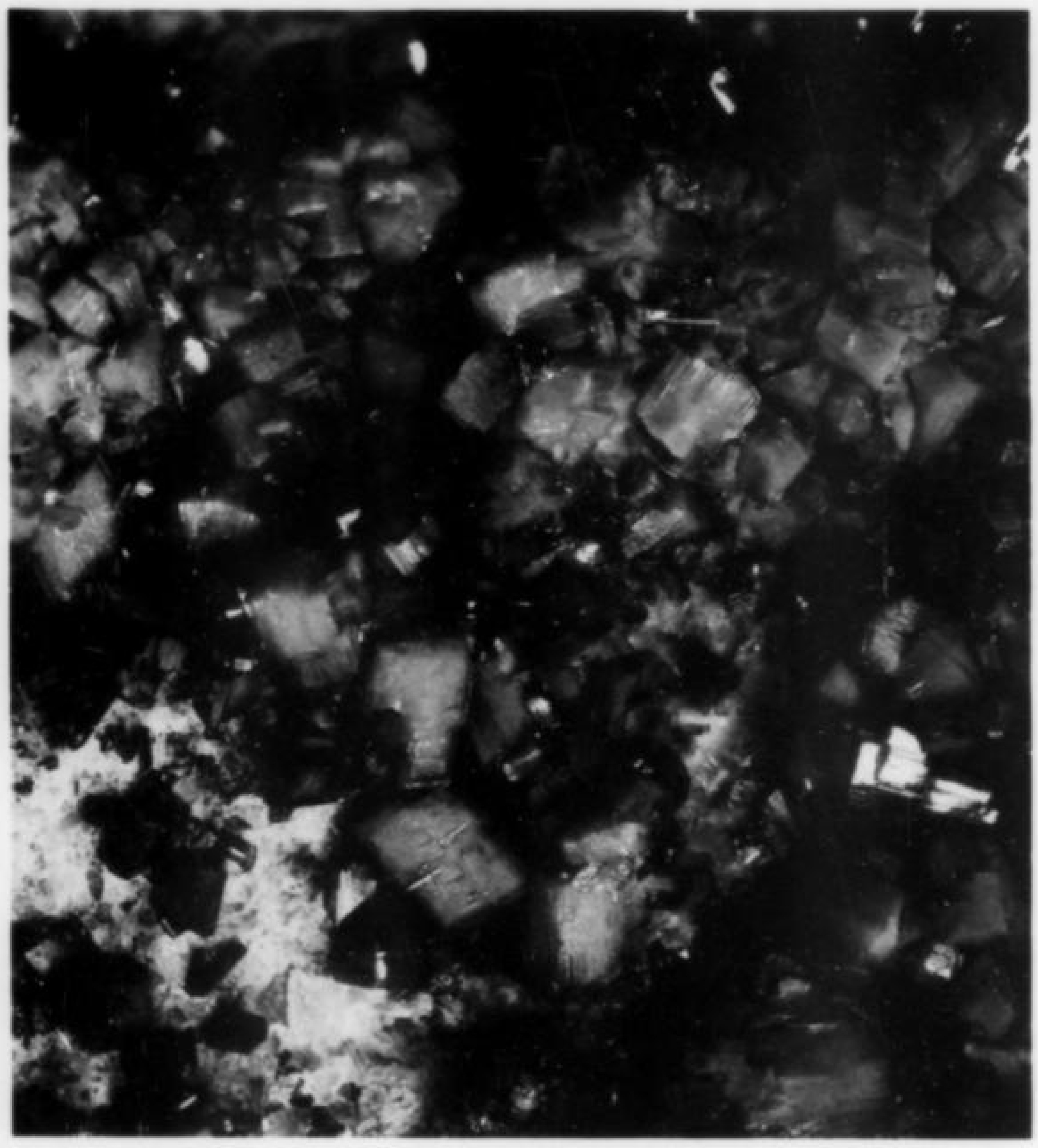

Figure 38. **Soddyite crystals to 1 mm from the Swambo mine. Sorbonne collection; Bariand photo.**

to canary-yellow in opaque crystals and greenish yellow in the fibrous masses. The maximum crystal size is about 3 mm. It is frequently associated with curite, and also with metatorbernite, sklodowskite and kasolite.

Shinkolobwe is the type locality for soddyite (Schoep, 1922b). It is also known at Musonoi and Kalongwe (associated with cuprosklodowskite and vandenbrandeite), and at Kambove and Luiswishi (Deliens *et al.*, 1981).

Particularly fine specimens of soddyite have been found at Swambo, where it occurs abundantly as yellow bipyramids {111} and elongated prisms to 5 mm. As at Shinkolobwe, the crystals are amber-yellow where transparent and canary-yellow where translucent or opaque. Some crystals show good phantoms; others are colored black by cobalt oxides and hydroxides. Associations include curite, uranophane, sklodowskite and swamboite.

Studtite $UO_4\cdot4H_2O$

Studtite occurs near uraninite as an alteration product, but in contrast to ianthinite, it is stable. Crystals are always whitish yellow to canary-yellow, acicular, up to 3 or 4 mm in size, radiating or intergrown as tufts and rosettes. The needles possess a certain amount of flexible elasticity.

Studtite cannot be distinguished visually from uranophane, with which it commonly occurs. Other associations include (more rarely) becquerelite, billietite and wölsendorfite.

Shinkolobwe is the type locality for studtite (Vaes, 1947; see also Walenta, 1974). It has also been found at Swambo (Deliens *et al.*, 1981).

Swamboite $U^{+6}H_6(UO_2)_6(SiO_4)_6\cdot30H_2O$

The Swambo mine (about 30 km west of Shinkolobwe) is the type locality for swamboite (Deliens and Piret, 1981). It occurs in pale yellow to lemon-yellow, transparent to translucent, acicular crystals up to 1 mm in size. The crystals, which closely resemble uranophane, are found as isolated individuals and as tufts and coatings in vugs commonly associated with soddyite. It is not fluorescent.

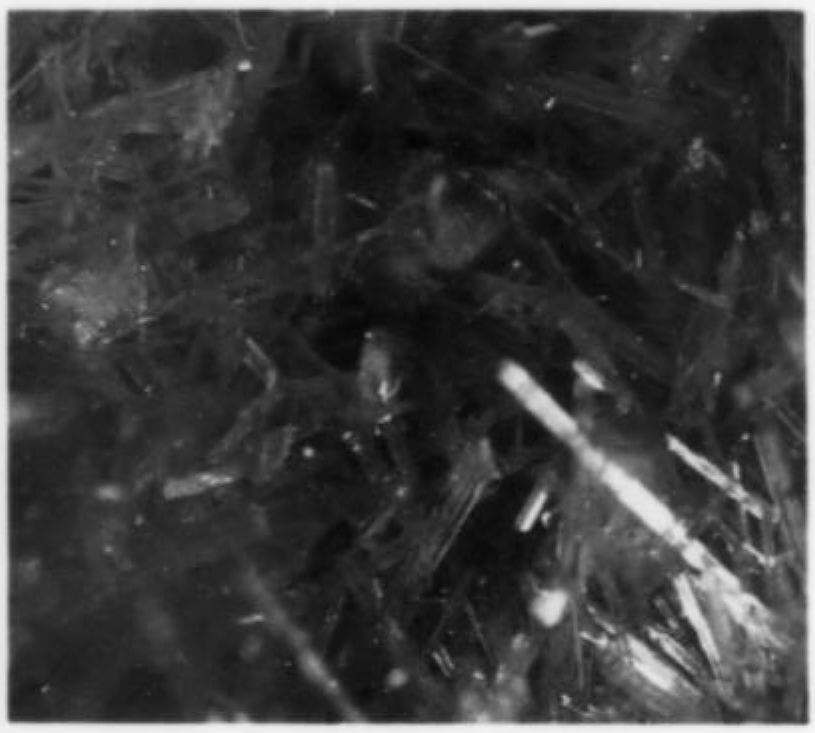

Figure 39. **Swamboite crystals from the Swambo mine. Collection and photo: W. Pinch.**

Figure 40. **Metatorbernite specimen, 11 cm across, from the Musonoi mine. Sorbonne collection; Bariand photo.**

Torbernite $Cu(UO_2)_2(PO_4)_2\cdot8–12H_2O$
and **Metatorbernite** $Cu(UO_2)_2(PO_4)_2\cdot8H_2O$

Almost all of the torbernite found during the course of mining at Shinkolobwe had already been dehydrated *in situ* to metatorbernite. In any case, whatever torbernite specimens were collected have since dehydrated as well. Crystals are abundant at Shinkolobwe, both in the deposit itself and also in the adjacent wall rocks. The so-called cellular siliceous rock layer (which normally separates the two copper-cobalt orebodies throughout the Shaba Crescent) was found to be riddled with vugs and pockets containing torbernite-metatorbernite.

Crystals are more or less square and thin, transparent to translucent depending on thickness, and come in all shades of green, from bright emerald-green to very dark green. Bipyramidal habits and tabular crystals having an octagonal outline are known as well. Crystal forms reported include {001}, {010}, {110}, {011}, {012} and {111}, with a perfect cleavage on {100}. Crystals consisting of epitaxial torbernite-metatorbernite and the magnesium analog, saleeite, have been reported (Deliens *et al.*, 1981).

Torbernite-metatorbernite has been found at Shinkolobwe, Musonoi, Kalongwe (with vandenbrandeite and cuprosklodowskite), and other deposits in the Shaba Crescent. Other associations include schoepite, curite, parsonsite, renardite, uranophane, sklodowskite and kasolite. Musonoi has yielded what are certainly the finest specimens of metatorbernite in the world: beautiful, large cabinet specimens densely covered by lustrous, dark green crystals to 2 or 3 cm.

Umohoite $(UO_2)MoO_4\cdot4H_2O$

Several varieties of umohoite have been found at Shinkolobwe, as small tablets, opaque to translucent and varying in color from black to bronze and dark green. Varieties containing 1% magnesium, 1%

nickel or 0.3% calcium (with 0.7% nickel) are known. The magnesian umohoite is the most common of these, occurring in bunches of dark green plates. Associations include uraninite, molybdenite, siegenite and iriginite (Deliens *et al.*, 1981).

Urancalcarite $Ca(UO_2)_3(CO_3)(OH)_6 \cdot 3H_2O$

Urancalcarite is the third of the new uranyl carbonates from Shinkolobwe. It occurs as bright yellow, acicular crystals forming fibrous crusts and radially fibrous nodules with a velvety surface. It is not fluorescent. Urancalcarite is very rare and has been found in association only with wyartite.

Shinkolobwe is the type locality for urancalcarite (Deliens and Piret, 1984).

Uranocircite $Ba(UO_2)_2(PO_4)_2 \cdot 12H_2O$

Uranocircite, which closely resembles autunite, has thus far been identified in only a single specimen from Shinkolobwe. It occurs as pale yellow tiny flakes.

Uranophane $Ca(UO_2)_2(SiO_3,OH)_2 \cdot 4H_2O$

Uranophane is the most common secondary uranium mineral at Shinkolobwe. It is found throughout the oxidation zone, as prismatic to acicular crystals. Most commonly it occurs as intergrown acicular masses on uraninite, and also as tufts and radial aggregates. Color ranges from lemon-yellow to straw-yellow, honey-yellow and greenish yellow. (Uranophane-beta has not been found at Shinkolobwe.) Common associations include curite, metatorbernite, sklodowskite, kasolite and rutherfordine.

Uranophane also occurs at many other deposits in Shaba including Kalongwe, Kambove, Kolwezi, Luiswishi, Musonoi and Swambo. At Swambo and Kolwezi it occurs with soddyite.

Uranopilite $(UO_2)_6(SO_4)(OH)_{10} \cdot 12H_2O$

Uranopilite, and also the sulfate zippeite, occur at Shinkolobwe only as post-mining minerals which form on the walls of stopes and on rubble during the dry season. It is found as yellow, botryoidal crusts.

Vandendriesscheite $PbU_7^{+6}O_{22} \cdot 12H_2O$

Vandendriesscheite is known in three principal habits: prismatic crystals having a pseudohexagonal cross-section; small, drum-shaped crystals; and bundles of acicular crystals, all elongated on [010]. Common crystal forms include {010}, {110}, {111} and {100}, with a {010} cleavage perpendicular to the elongation. The crystals are transparent to translucent, and orange to amber-yellow and pale yellow in the thinnest crystals. Associations include becquerelite, fourmarieite, rutherfordine, torbernite, metatorbernite and uranophane.

Shinkolobwe is the type locality for vandendriesscheite (Vaes, 1947).

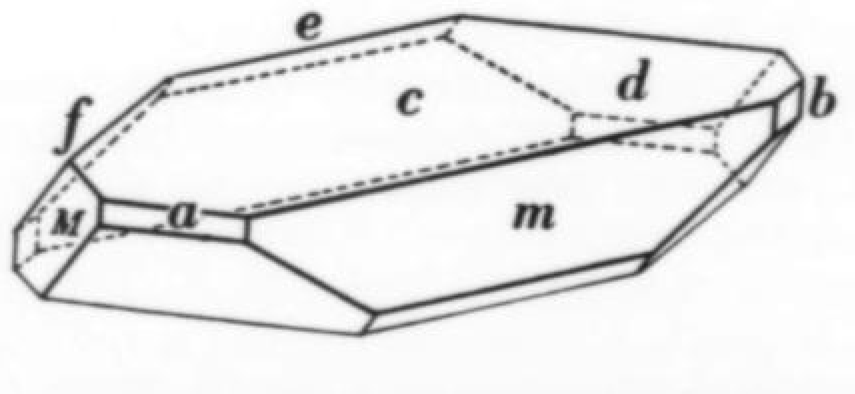

***Figure 41*. Crystal drawing of vandenbrandeite from Kalongwe (Milne and Nuffield, 1951).**

Vandenbrandeite $Cu(UO_2)(OH)_4$

Vandenbrandeite occurs in two habits: as small, flattened {001}, tabular crystals which tend to be somewhat rounded; and elongated, often very brilliant bipyramidal crystals, alone or in groups. It also occurs in compact masses.

The color (as might be expected of a copper mineral) is typically a dark green with bluish internal reflections. Crystals range from 0.5 mm (tabular) to 1 mm (bipyramidal) at Shinkolobwe, but much larger crystals up to 1 cm have been found at other mines in the Shaba Crescent. Associations include uranophane, curite, kasolite, cuprosklodowskite, malachite and heterogenite.

Kalongwe, Shaba, is the type locality for vandenbrandeite (Schoep, 1932). It is also known from Musonoi, Shinkolobwe, Kambove, Luiswishi and Swambo.

Wölsendorfite $(Pb,Ca)U_2O_7 \cdot 2H_2O$

Wölsendorfite occurs as flattened, prismatic to tabular crystals to 2 mm commonly twinned in pseudohexagonal tablets. Twins with up

***Table 1*. Minerals of the Shinkolobwe mine.**

Uranium Minerals

Oxides and uranates:
- Becquerelite*
- Billietite*
- Curite*
- Fourmarierite*
- Ianthinite*
- Masuyite*
- Metaschoepite*
- Metastudtite*
- Protasite*
- Richetite*
- Sayrite*
- Schoepite*
- Studtite*
- Uraninite
- Vandenbrandeite
- Vandendriesscheite*
- Wölsendorfite

Carbonates:
- Bijvoetite-(Y)*
- Lepersonnite-(Gd)*
- Liebigite
- Roubaultite*
- Rutherfordine*
- Sharpite*
- Urancalcarite*
- Wyartite*

Phosphates-arsenates:
- Dewindtite*
- Dumontite*
- Metatorbernite
- Parsonsite*
- Phosphuranylite
- Phurcalite
- Renardite*
- Saléeite*
- Torbernite
- Uranocircite
- Zeunerite (As)

Silicates:
- Beta-uranophane
- Cuprosklodowskite
- Kasolite*
- Oursinite*
- Sklodowskite*
- Soddyite*
- Uranophane

Molybdates and vanadates:
- Curiénite
- Iriginite
- Sengierite
- Umohoite

Tellurates:
- Schmitterite

Selenites:
- Guilleminite

Sulfates:
- Uranopilite
- Zippeite

Non-Uranium Minerals

Anhydrite
Aragonite
Asbolane
Barite
Bornite
Bravoite
Brochantite
Calcite
Carrollite
Cattierite
Chalcocite
Chalcopyrite
Chlorite
Chrysocolla
Clausthalite
Comblainite*
Copper
Covellite
Cyanotrichite
Devilline
Digenite
Dioptase
Dolomite
Fluorapatite
Galena
Goethite
Gold
Hematite
Heterogenite
Jarosite
Kolbeckite
Linnaeite
Lizardite
Magnesite
Malachite
Melonite
Millerite
Molybdenite
Molybdite
Monazite
Morenosite
Muscovite
Nepouite
Opal
Palladium
Penroseite
Pentlandite
Platinum
Polydymite
Pseudomalachite
Pyrite
Pyromorphite
Quartz
Rutile
Scapolite
Siegenite
Sphalerite
Spinelle
Stilleite
Talc
Tourmaline
Trogtalite
Umangite
Vaesite
Variscite
Volborthite
Wulfenite

*First described from the deposit.

to six individuals, and also cockscomb-habit plates and groups are known. The mineral also occurs in a fibrous acicular habit as radially structured nodules, bright red to carmine-red and orange-red in color. It is associated with many of the hydrous uranyl oxides, the uranates of Pb, Ba and Ca, and also wyartite and uranophane (Deliens *et al.*, 1981).

Wyartite $Ca_3U^{+4}(UO_2)_6(CO_3)_2(OH)_{18}\cdot 3\text{–}5H_2O$

Wyartite occurs as flattened and elongated crystals grouped in flabelliform aggregates. Fresh samples are black to purplish black in color, gradually becoming yellowish brown to greenish brown upon alteration. Ultimately it alters to yellow schoepite. Crystals are transparent to opaque. Associations include wölsendorfite and rutherfordine.

Shinkolobwe is the type locality for wyartite (Guillemin and Protas, 1959).

Zeunerite $Cu(UO_2)_2(AsO_4)_2\cdot 10\text{–}16H_2O$

Zeunerite has been found recently (1987) in the KOV mine, at Kamoto. It occurs as square green tablets resembling torbernite but more brittle. The use of X-ray diffraction is necessary to distinguish between the two species. This is the first occurrence of a uranyl arsenate in the deposits of southern Shaba.

Zippeite $K_4(UO_2)_6(SO_4)_3(OH)_{10}\cdot 4H_2O$

Zippeite, and also the sulfate uranopilite, occur at Shinkolobwe only as post-mining minerals which form on rubble and stope walls during the dry season. It is found as yellow-orange microcrystalline aggregates.

Table 2. **Minerals of the Swambo mine.**

Uranium Minerals
Billietite
Curite
Ianthinite
Kasolite
Metatorbernite
Renardite
Sklodowskite
Soddyite
Studtite
Swamboïte*
Uraninite
Uranophane
Vandenbrandeite

Non-Uranium Minerals
Goethite
Gold
Gypsum
Hematite
Heterogenite
Lizardite
Malachite
Siegenite

*First described from the deposit.

Table 3. **Minerals of the Musonoi mine.**

Uranium Minerals
Becquerelite
Beta-uranophane
Cuprosklodowskite
Curite
Demesmaekerite*
Derriksite*
Francevillite
Guilleminite*
Kasolite
Marthozite*
Masuyite
Metatorbernite
Metatyuyamunite
Rutherfordine
Sengierite
Schoepite
Sklodowskite
Soddyite
Tyuyamunite
Uraninite
Uranophane
Vandenbrandeite

Non-Uranium Minerals
Azurite
Barite
Brochantite
Chalcocite
Chalcomenite
Cobaltomenite
Digenite (selenian)
Gold
Hematite
Heterogenite
Malachite
Mottramite
Oosterboschite*
Palladium
Trogtalite
Vauquelinite
Wulfenite

*First described from the deposit.

Table 4. **Uranium minerals of the Kamoto mine.**

The species below are found at the Kamoto-Principal, Kamoto-East and KOV deposits. The non-uranium mineral assemblage, not listed here, closely resembles that of Musonoi.

Francevillite
Françoisite-(Nd)*
Kamotoite-(Y)*
Masuyite
Metasaleeite
Metastudtite
Metatorbernite
Phosphuranylite
Roubaultite
Shabaite-(Nd)*
Sklodowskite
Uraninite
Uranophane
Zeunerite

*First described from the deposit.

ACKNOWLEDGMENTS

We wish to thank Pierre and Nelly Bariand for kindly supplying photography (much of it never before published), and Dr. Wendell Wilson for arranging the English translation and merging the work of the various authors into one article.

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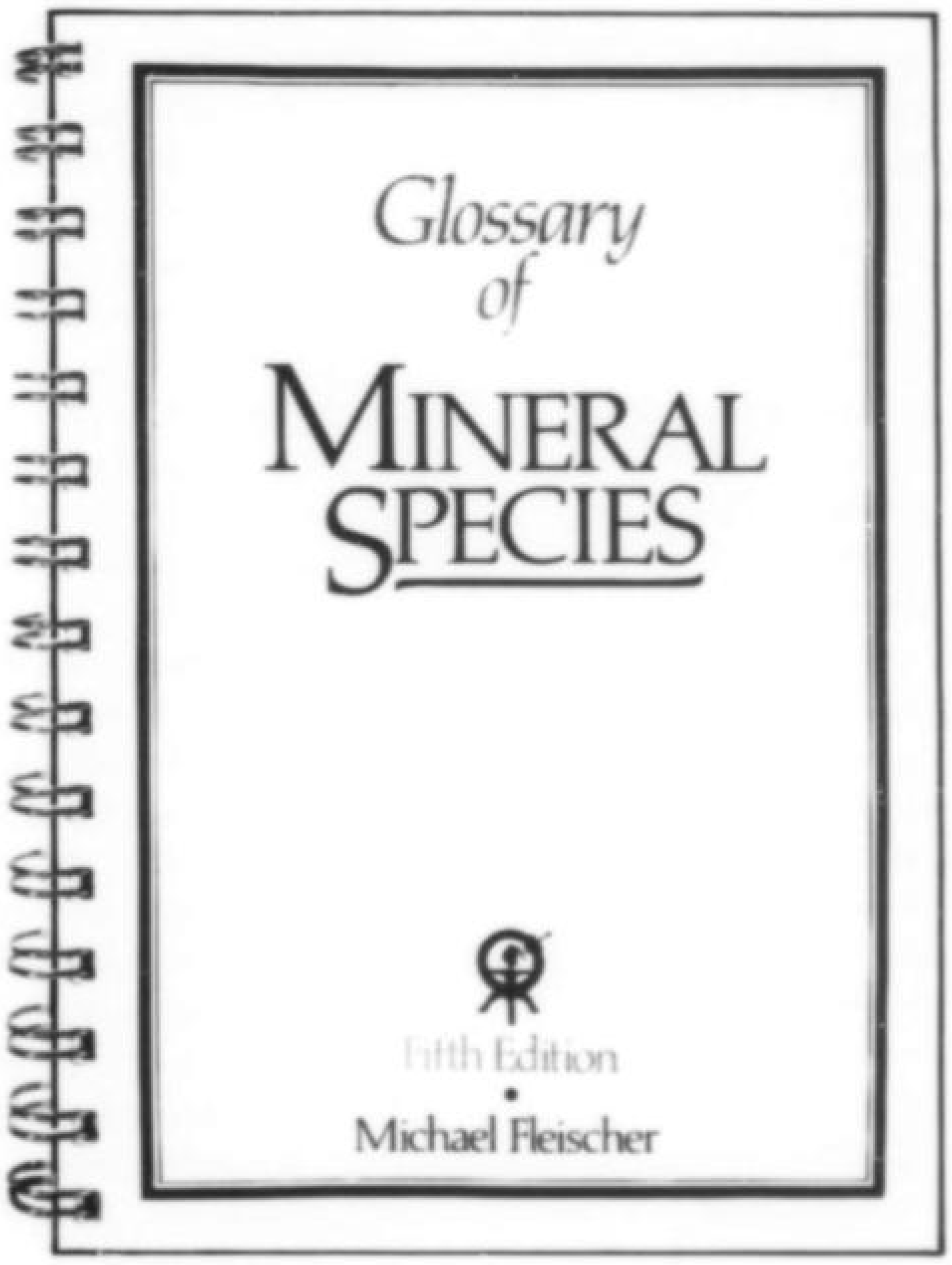
(continued on page 304)

Additions and Corrections to the
Glossary of Mineral Species, 5th Edition (1987)

Michael Fleischer



PREFACE

The flood of new mineralogical data has continued. This update of the *Glossary of Mineral Species*, 5th Edition (1987) covers the data published from Sept. 30, 1986 to Jan. 1, 1989. It includes 700 items, including 122 newly described minerals, marked with an asterisk.* In addition, seven new mineral groups have been added, and the nomenclature of the Pyroxene Group has been changed to conform to that recommended by the International Mineralogical Association's Commission on New Minerals and Mineral Names, published in *American Mineralogist*, **73,** 1123–1133 (1988).

Journal references given without specific attribution in this update are to the *American Mineralogist*.

I am indebted to many persons who have made suggestions for improvement of the *Glossary*, and especially to Peter Bayliss, University of Calgary; Dr. Pete Dunn, Smithsonian Institution; E. H. Nickel, C.S.I.R.O., West Australia; Andrew L. Palmer, Mayfield, N.Y.; G. W. Shokal, San Carlos, Calif., and John S. White, Smithsonian Institution. I shall be glad to hear from others; please write to me at the Department of Mineral Sciences, Smithsonian Institution, Washington, D.C. 20560.

My wife, Helen I. Fleischer, has carefully checked this update and corrected many errors, and the final draft was further checked by John S. White of the Smithsonian Institution and by J. A. Mandarino of the Royal Ontario Museum, Toronto, whose help is deeply appreciated.

Page

1 Acmite, change the entry to Acmite = **Aegirine**
1 ***Acuminite,** $SrAlF_4(OH)\cdot H_2O$, mon., dimorph. with **Tikhonenkovite, 73,** 1492 (1988)
1 Aegirine, change to **Aegirine** (Acmite), $NaFe^{+3}Si_2O_6$, mon., *Pyroxene* group
1 **Aerinite,** $Ca_4(Al,Fe^{+3},Mg,Fe^{+2})_{10}Si_{12}O_{36}(OH)_{12}(CO_3)\cdot 12H_2O$, mon., fibrous, sky-blue, **73,** 1498–1499 (1988)
1 **Aeschynite-(Ce),** (after orth.), add dimorph. with **Lucasite-(Ce)**
2 **Akaganeite,** add **56,** 639 (1971)
3 **Akrochordite,** add **53,** 1779 (1968)
3 **Alacranite,** add **73,** 189 (1988)
4 **Alleghanyite,** (after mon.), add dimorph. with **Ribbeite**
4 **Alluaudite,** change the formula to $NaCaFe^{+2}(Mn,Fe^{+2},Fe^{+3},Mg)_2(PO_4)_3$, delete compare **Hagendorfite, Maghagendorfite,** replace by *Alluaudite* group
4 ***Althupite,** $ThAl(UO_2)_7(PO_4)_4O_2(OH)_5\cdot 15H_2O$, tric., yellow, **73,** 189–190 (1988)
4 **Aluminocopiapite,** change the formula to $Al_{2/3}Fe_4^{+3}(SO_4)_6(OH)_2\cdot 20H_2O$

4 **Aluminokatophorite,** in the formula change Si_7Al to (Si_7Al)

5 ***Ammonioalunite,** $(NH_4)Al_3(SO_4)_2(OH)_6$, trig., *Alunite* group, **73,** 145–152 (1988)

6 ***Amstallite,** $CaAl(Si,Al)_4O_8(OH)_4\cdot(H_2O,Cl)$, mon., **73,** 1492 (1988)

6 **Andremeyerite,** add **73,** 608–612 (1988)

8 ***Argentotennantite,** $(Ag,Cu)_{10}(Zn,Fe)_2(As,Sb)_4S_{13}$, cub., forms a series with **Freibergite,** *Tetrahedrite* group, **73,** 439 (1988)

9 **Arhbarite,** after the formula, add mon. (?)

9 **Armalcolite,** delete **Kennedyite,** add **73,** 1377–1383 (1988)

9 ***Arseniopleite,** $NaCaMn(Mn,Mg)_2(AsO_4)_3$, mon., **Alluaudite** group, **73,** 666 (1988)

10 **Arseniosiderite,** change the formula to $Ca_2Fe_3^{+3}(AsO_4)_3O_2\cdot 3H_2O$

10 ***Arsenoflorencite-(Ce),** $(Ce,La)Al_3(AsO_4)_2(OH)_6$, trig., *Crandallite* group, **73,** 1492–1493 (1988)

10 **Arthurite,** delete compare **Earlshannonite, Ojuelaite, Whitmoreite,** replace by *Arthurite* group

10 **Asbecasite,** add **55,** 1818 (1970)

10 Ascharite = **Szaibelyite**

11 **Ashcroftine-(Y),** change the formula to $K_5Na_5(Y,Ca)_{12}Si_{28}O_{70}(OH)_2(CO_3)_8\cdot 3H_2O$, add **72,** 1176–1189 (1987)

11 ***Ashoverite,** $Zn(OH)_2$, tet., polymorph. with **Sweetite** and **Wülfingite,** Min. Mag. **52,** 699–702 (1988)

11 ***Asisite,** $Pb_7SiO_8Cl_2$, tet., yellow to yellow-green, **73,** 643–650 (1988)

11 Astrakhanite, change **Bloedite** to **Blödite**

11 ***Atlasovite,** $Cu_6Fe^{+3}BiO_4(SO_4)_5\cdot KCl$, tet., tabular, forms a series with **Nabokoite, 73,** 927 (1988)

11 **Aubertite,** change compare **Svyazhinite** to compare **Magnesioaubertite** and **Svyazhinite**

11 *Aurantimonate, $AuSbO_3$

13 **Baghdadite,** delete Min. Mag. **50,** 119–123 (1986), replace by **72,** 222 (1987)

13 ***Baileychlore,** $(Zn,Fe^{+2},Al,Mg)_6(Si,Al)_4O_{10}(OH)_8$, tric., *Chlorite* group, green, **73,** 135–138 (1988)

13 ***Baiyuneboite-(Ce),** $BaNaCe_2(CO_3)_4F$, hex., yellow

13 **Balangeroite,** change the formula to $(Mg,Fe^{+3},Fe^{+2},Mn^{+2})_{42}Si_{16}O_{54}(OH)_{40}$, change orth. to mon., add compare **Gageite**-1Tc, **Gageite**-2M, **72,** 382–391 (1987)

13 Balavinskite, should not be in bold face

13 **Balipholite,** in the formula change $(OH)_8$ to $(OH,F)_8$

13 **Bambollaite,** change the formula to $Cu(Se,Te)_2$

13 **Banalsite,** after *Feldspar* group, add compare **Stronalsite**

14 **Barbosalite,** delete compare **Lazulite, Scorzalite** and replace by *Lazulite* group

14 Change **Barium-pharmacosiderite** to Bariumpharmacosiderite (not bold face)

15 *Bayankhanite, Cu_6HgS_4, **71,** 1543 (1986)

16 ***Bazhenovite,** $CaS_5\cdot CaS_2O_3\cdot 6Ca(OH)_2\cdot 20H_2O$, mon., orange

16 **Bazzite,** add **52,** 563–564 (1967)

16 **Becquerelite,** add **72,** 1230–1238 (1987)

16 **Benavidesite,** delete compare **Jamesonite** and replace by forms a series with **Jamesonite**

16 ***Benleonardite,** $Ag_8(Sb,As)Te_2S_3$, tet., **73,** 439 (1988)

18 **Berzeliite,** after group, add and **Palenzonaite**

18 **Bezsmertnovite,** delete **68,** 1248 (1983), replace by **66,** 878 (1981)

18 **Billietite,** change formula to $Ba(UO_2)_6O_4(OH)_6\cdot 4H_2O$, add **72,** 1230–1238 (1987)

19 **Bismoclite,** after tet., add yellow, brown

20 ***Blatterite,** $(Mn^{+2},Mg)_2(Mn^{+3},Sb^{+3},Fe^{+3})BO_5$, orth., black, compare **Orthopinakiolite, Takeuchiite**

20 ***Blossite,** alpha-$Cu_2V_2^{+5}O_7$, orth., dimorph. with **Ziesite, 72,** 397–400 (1987)

20 ***Bobfergusonite,** $Na_2Mn_5^{+2}Fe^{+3}Al(PO_4)_6$, mon., red-brown to greenish-brown, **73,** 190 (1988)

20 **Boltwoodite,** change formula to $HK(UO_2)SiO_4\cdot 1\tfrac{1}{2}H_2O$

21 Bonchevite = a mixture of **Pekoite** and **Galenobismutite, 55,** 1449 (1970, **73,** 666 (1988)

22 Brammallite, change sodium rich to sodium-rich, **Illite** to *Illite*

22 **Brandtite,** replace compare **Roselite** by dimorph. with **Parabrandtite,** *Roselite* group

22 **Bredigite,** change the formula to $Ca_7Mg(SiO_4)_4$

23 ***Brokenhillite,** $(Mn,Fe)_8Si_6O_{15}(OH,Cl)_{10}$, hex., dimorph. with **Manganpyrosmalite**

23 **Brownmillerite,** after orth., add compare **Srebredolskite**

24 **Burbankite,** replace compare **Carbocernaite, Khanneshite** with compare **Khanneshite** and **Remondite-(Ce)**

25 **Byströmite,** delete compare **Ordonezite,** replace by *Tapiolite* group

26 **Cacoxenite,** in the formula, change $17H_2O$ to $75H_2O$

26 **Calcioferrite,** change to $Ca_4Fe^{+2}(Fe^{+3},Al)_4(PO_4)_6(OH)_4\cdot 12H_2O$, mon., yellow-green, *Montgomeryite* group

26 ***Calciohilairite,** $CaZrSi_3O_9\cdot 3H_2O$, trig., white to pale blue, compare **Hilairite, 73,** 1191–1194 (1988)

27 **Calomel,** after tet., add forms a series with **Kuzminite**

27 **Cameronite,** delete Can. Min. **24,** 379–384 (1986), add **72,** 1023 (1987)

27 **Canaphite,** change the formula to $CaNa_2P_2O_7\cdot 4H_2O$, add **73,** 168–171 (1988)

28 **Carbocernaite,** delete compare **Burbankite**

28 **Carbonate-hydroxylapatite,** change Dahlite to Dahllite

28 **Carletonite,** add **57,** 765–778 (1972)

29 **Carlosturanite,** in the formula, change (OH) to $(OH)_{34}$

29 **Caryinite,** change the formula to $Na(Ca,Pb)(Ca,Mn)(Mn,Mg)_2(AsO_4)_3$, add *Alluaudite* group, **73,** 606–607 (1988)

29 Caryocerite, change **Melanocerite** to **Melanocerite-(Ce)(?)**

29 ***Cassedanneite,** $Pb_5(VO_4)_2(CrO_4)_2\cdot H_2O$, mon., red-orange, **73,** 1493 (1988)

30 **Cattierite,** change to forms two series, with **Pyrite,** and with **Vaesite**

30 **Caysichite-(Y),** change formula to $Ca_3Y_4GdSi_8O_{20}(CO_3)_6(OH)\cdot 2H_2O$

30 **Cebaite-(Ce),** in the formula change (CO_3) to $(CO_3)_5$

30 **Cebaite-(Nd),** add **73,** 1493 (1988)

30 **Cebollite,** change the formula to $Ca_2(Mg,Fe^{+2},Al)Si_2(O,OH)_7$

30 Cenosite, change **Kainosite** to **Kainosite-(Y)**

31 ***Cesplumtantite,** $(Cs,Na)_2(Pb,Sb^{+3})_3Ta_8O_{24}$, tet.

31 ***Cetineite,** $(K,Na)_{3-x}(Sb_2O_3)_3(SbS_3)(OH)_x\cdot(3-x)H_2O$, $x\sim 0.5$, hex., orange-red, **73,** 398–404 (1988)

31 **Chabourneite,** change the formula to $(Tl,Pb)_{21}(Sb,As)_{91}S_{147}$

31 ***Chaidamuite,** $(Zn,Fe^{+2})(Fe^{+3})(SO_4)_2(OH)\cdot 4H_2O$, mon., brown to yellow-brown

32 **Chalcophanite,** change tric. to trig., add **73,** 1401–1404 (1988)

33 **Charoite,** change the formula to $K(Ca,Na)_2Si_4O_{10}(OH,F)\cdot H_2O$

33 ***Chekhovicite,** $Bi_2Te_4^{+4}O_{11}$, mon., Min. Abs. **39,** p. 693 (1988)

33 **Chenite,** delete Min. Mag. **50,** 129–135 (1985), replace by **72,** 222 (1987)

33 **Cherepanovite,** add **71,** 1544 (1986)

33 ***Chernikovite** (hydrogen autunite), $(H_3O)_2(UO_2)_2(PO_4)_6\cdot 2H_2O$, tet., pale yellow, **Meta-autunite** group, Min. Record **19,** 249–252 (1988)

33 ***Chestermanite,** $Mg_2(Fe^{+3},Mg,Al,Sb^{+5})BO_5$, orth., gray-green to black, **Ludwigite** group, Can. Min. **26,** 911–915 (1988)
33 **Chiavennite,** in the formula, change (OH) to $(OH)_2$
34 ***Chlorellestadite,** $Ca_5(SiO_4,PO_4,SO_4)_3(Cl,F)$, hex., compare **Fluorellestadite, Hydroxylellestadite, Mattheddleite,** related to the *Apatite* group, **67,** 90–96 (1982)
34 **Chromferide,** add **73,** 190 (1988)
35 **Chvaleticeite,** add **72,** 1023 (1987)
35 ***Chvilevaite,** $Na(Cu,Fe,Zn)_2S_2$, hex., bronze color
36 Clinochalcomenite, should not be in bold face
36 **Clinoferrosilite,** change **Orthoferrosilite** to **Ferrosilite**
36 **Clinohedrite,** change the formula to $CaZnSiO_4\cdot H_2O$
37 ***Cobaltaustinite,** $CaCo(AsO_4)(OH)$, mon., green, **Adelite** group, Min. Abs. **39,** p. 694 (1988)
40 ***Criddleite,** $TlAg_2Au_3Sb_{10}S_{10}$, mon., Min. Mag. **52,** 691–697 (1988)
40 **Crookesite,** change the entry to $Cu_7(Tl,Ag)Se_4$, tet., **73,** 933 (1988)
41 **Cualstibite,** add **70,** 1329 (1985)
41 **Cubanite,** add dimorph. with **Isocubanite**
41 **Cupalite,** add **71,** 1278 (1986)
41 Cuprofaustite = **Faustite**
41 **Cuproiridsite,** add **71,** 1277 (1986)
41 **Cuprorhodsite,** add **71,** 1277 (1986)
43 ***Danielsite,** $(Cu,Ag)_{14}HgS_8$, orth., **72,** 401–403 (1987); **73,** 187–188 (1988)
43 ***Davidite-(Ce),** $(Ce,La)(Y,U,Fe^{+2})(Ti,Fe^{+3})_{20}(O,OH)_{38}$, trig., *Crichtonite* group
43 Davisonite, change the entry to a mixt. of **Crandallite** and **Apatite, 71,** 1515–1516 (1986)
43 Dayingite, should not be in bold face
43 **Defernite,** change the formula to $Ca_6(CO_3)_{2-x}(SiO_4)_x(OH)_7(Cl,OH)_{1-2x}$, x 0.5, add **73,** 888–893 (1988)
43 ***Delindeite,** $(Na,K)_3(Ba,Ca)_4(Ti,Fe,Al)_6Si_8O_{26}(OH)_4$, mon., pinkish-gray, **73,** 1493–1494 (1988)
43 **Denisovite,** in the formula, change $(F,OH)_2$ to (F,OH)
43 Dennisonite, delete the entire entry
45 **Diaspore, Bracewellite** is misspelled
46 ***Diomignite,** $Li_2B_4O_7$, tet., **73,** 928 (1988)
46 ***Dollaseite-(Ce),** $CaCeMg_{24}AlSi_3O_{11}(OH,F)_2$, mon., **Epidote** group, **73,** 838–842 (1988)
46 ***Dorrite,** $Ca_2Mg_2Fe_4^{+3}Al_4Si_2O_{20}$, tric., **Aenigmatite** group, **73,** 1440–1448 (1988)
47 **Drugmanite,** change the formula to $Pb_2(Fe^{+3},Al)H(PO_4)_2(OH)_2$, add structurally related to the silicates of the *Gadolinite* group
47 **Dumontite,** change the formula to $Pb_2(UO_2)_3O_2(PO_4)_2\cdot 5H_2O$
49 **Earlshannonite,** delete compare **Arthurite, Ojuelaite, Whitmoreite,** replace by *Arthurite* group
49 ***Ecandrewsite,** $(Zn,Fe^{+2},Mn^{+2})TiO_3$, trig., *Ilmenite* group, Min. Mag. **52,** 237–240 (1988)
49 **Edenite,** in the formula change Si_7Al to (Si_7Al)
49 **Eglestonite,** change the formula to $Hg_6Cl_3O(OH)$ (?), add (after brownish-yellow) forms a series with **Kadyrelite**
49 **Ehrleite,** change the formula to $Ca_2ZnBe(PO_4)_2(PO_3OH)\cdot 4H_2O$, add Can. Min. **25,** 767–774 (1987)
49 **Eifelite,** add (after hex.), forms a series with **Roedderite**
49 **Eitelite,** delete forms a series with **Roedderite**
50 **Ellenbergerite,** add **73,** 190–191 (1988)
51 **Enstatite,** change **Orthoferrosilite** to **Ferrosilite,** and delete and **Hypersthene**
51 **Ephesite,** (after mon.) add or tric.
51 **Epistilbite,** add **73,** 1434–1439 (1988)
51 **Erlianite,** delete Min. Mag. **50,** 285–289 (1986), replace by **72,** 1023–1024 (1987)
51 **Ertixiite,** add Min. Mag. **52,** 724 (1988)
52 ***Esseneite,** $CaFe^{+3}AlSiO_6$, mon., reddish-brown, *Pyroxene* group, **72,** 148–156 (1987)
53 **Evenkite,** change the formula to $C_{24}H_{50}$
53 **Eztlite,** in the formula change Pb_3 to Pb_2
54 ***Fahleite,** $Zn_5CaFe_2^{+3}(AsO_4)_6\cdot 14H_2O$, orth. (?), yellow to gray to green, compare **Smolianinovite,** Min. Abs. **39,** p. 694 (1988)
54 Falkmanite, not in bold face, add **73,** 667 (1988)
54 Fassaite, not in bold face, delete the text, replace by = ferrian aluminian **Diopside** or **Augite**
54 ***Fedotovite,** $K_2Cu_3^{+2}O(SO_4)_3$, mon., green
55 **Ferchromide,** add **73,** 191 (1988)
55 **Ferricopiapite,** change the formula to $Fe_{2/3}^{+3}Fe_4^{+3}(SO_4)_6(OH)_2\cdot 20H_2O$
56 **Ferrierite,** change the formula to $(Na,Ka)_2Mg(Si,Al)_{18}O_{36}(OH)\cdot 9H_2O$
56 **Ferrikatophorite,** in the formula change Si_7Al to (Si_7Al)
56 **Ferrimolybdite,** after the formula, add orth. (?)
56 ***Ferristrunzite,** $Fe^{+3}Fe_2^{+3}(PO_4)_2(OH)_3\cdot 5H_2O$, tric., brownish-yellow, compare **Ferrostrunzite** and **Strunzite**
56 **Ferritungstite,** change the formula to $(K,Ca,Na)(W,Fe^{+3})_2(O,OH)_6\cdot H_2O$, add (after yellow), related to the *Pyrochlore* group
56 **Ferro-alluaudite,** in the formula, change (Na,Ca) to NaCa. Delete compare **Hagendorfite** and **Maghagendorfite;** replace by **Alluaudite** group
57 **Ferro-edenite,** in the formula, replace Si_7Al by (Si_7Al)
57 **Ferroferritschermakite,** in the formula, replace Si_6Al_2 by (Si_6Al_2)
58 **Ferrokaersutite,** in the formula, replace Si_6Al_2 by (Si_6Al_2)
58 ***Ferrokesterite,** $Cu_2(Fe,Zn)SnS_4$, tet., dimorph. with **Stannite,** compare **Kesterite**
58 ***Ferropyrosmalite,** $(Fe^{+2},Mn)_8Si_6O_{15}(Cl,OH)_{10}$, hex., forms a series with **Manganpyrosmalite, 73,** 933–934 (1988)
58 Ferrosilite, delete the entire entry and replace with **Ferrosilite** (Orthoferrosilite), $(Fe^{+2},Mg)_2Si_2O_6$, orth., dark green, forms a series with **Enstatite,** dimorph. with **Clinoferrosilite,** *Pyroxene* group
58 **Ferrostrunzite,** change compare **Strunzite** to compare **Ferristrunzite** and **Strunzite**
58 **Ferrotychite,** (after **Tychite**), add compare **Northupite**
59 ***Filipstadite,** $(Mn,Mg)_4Sb^{+5}Fe^{+3}O_8$, orth., black, **73,** 413–419 (1988)
59 **Flinkite,** change the formula to $Mn_2^{+2}Mn^{+3}(AsO_4)(OH)_4$
59 **Florencite-(La),** delete **69,** 566 (1984); replace by Can. Min. **18,** 301–311 (1980)
60 **Fluorellestadite,** (after **Hydroxylellestadite**), add compare **Chlorellestadite** and **Mattheddleite**
60 **Foordite,** (after mon.), add brownish-yellow; (after **Thoreaulite**), add Can. Min. **26,** 889–903 (1988)
60 **Formanite-(Y),** (after **Fergusonite-(Y),** add dimorph. with **Yttrotantalite-(Y)**
61 ***Franciscanite,** $Mn_3^{+2}V(SiO_4)(O,OH)_7$, hex., dark reddish-brown, compare **Örebroite, Welinite, 71,** 1522–1526 (1986)
61 ***Francoisite-(Nd),** $(Nd,Y,Sm,Ce)(UO_2)_3(PO_4)_2O(OH)\cdot 6H_2O$, mon., yellow
61 ***Franklinfurnaceite,** $Ca_2(Fe^{+3},Al)Mn^{+3}Mn_3^{+2}Zn_2Si_2O_{10}(OH)_8$, mon., dark brown, compare *Chlorite* group, **72,** 812–815 (1987), **73,** 876–887 (1988)
61 **Freedite,** change the formula to $Pb_8Cu^{+1}(As^{+3}O_3)_2O_3Cl_5$, add **73,** 667 (1988)
61 **Freibergite,** change forms a series with **Tetrahedrite** to forms 2 series, with **Argentotennantite,** and with **Tetrahedrite**

62 **Frohbergite,** delete **33,** 209 (1948), replace by **32,** 210 (1947)
62 **Furongite,** change the formula to $Al_2(UO_2)(PO_4)_3(OH)_2\cdot 8H_2O$, add **73,** 198 (1988)
63 ***Gageite-1Tc,** $(Mn,Mg,Zn)_{42}Si_{16}O_{54}(OH)_{40}$, tric., dimorph. with **Gageite-2M,** compare **Balangeroite, 72,** 382–391 (1987)
63 **Gageite,** change the entry to read **Gageite-2M,** $(Mn,Mg,Zn)_{42}Si_{16}O_{54}(OH)_{40}$, mon., dimorph. with **Gageite-1Tc,** compare **Balangeroite, 72,** 382–391 (1987)
63 **Gaitite,** (after tric.), add dimorph. with **Zincrosasite,** forms a series with **Talmessite,** *Fairfieldite* group
63 **Gamagarite,** change the formula to $Ba_2(Fe^{+3},Mn^{+3})(VO_4)_2(OH)$
64 **Gananite,** add **73,** 1494 (1988)
64 **Ganomalite,** change the formula to $Pb_9Ca_5Mn^{+2}Si_9O_{33}$; delete compare **Nasonite,** add **72,** 1028 (1977)
64 ***Gasparite-(Ce),** $(Ce,La,Nd)AsO_4$, mon., brownish-red, *Monazite* group, **73,** 1494–1495 (1988)
65 **Geikielite,** delete compare **Pyrophanite,** replace by *Ilmenite* group
65 **Gerdtremmelite,** change the formula to $(Zn,Fe^{+2})(Al,Fe^{+3})_2(AsO_4)(OH)_5$
66 Ginzburgite (not in bold face), $Ca_4Al_4Be_2Si_7O_{24}(OH)_4\cdot 3H_2O$, tet., **73,** 439–440 (1988) (= **Roggianite**)
66 **Glaucocerinite,** add **72,** 1028 (1987)
67 **Godlevskite,** add Min. Abs. **39,** p. 585 (1988)
67 ***Godovikovite,** $(NH_4)(Al,Fe^{+3})(SO_4)_2$, hex.
69 **Grischunite,** add **72,** 1225–1229 (1987)
69 ***Grumantite,** $NaHSi_2O_5\cdot H_2O$, orth., **73,** 440 (1988)
70 **Gyrolite,** change the formula to $NaCa_{16}Si_{23}AlO_{60}(OH)_8\cdot 64H_2O$
71 **Hagendorfite,** in the formula, change (Na,Ca) to NaCa; delete compare **Alluaudite, Ferro-alluaudite, Maghagendorfite** and replace by *Alluaudite* group
72 **Hannebachite,** add **73,** 928 (1988)
72 **Harstigite,** change the formula to $Ca_6MnBe_4(SiO_4)_2(Si_2O_7)_2(OH)_2$
72 **Hashemite,** add **71,** 1217–1220 (1986)
72 **Hastingsite,** in the formula, change Si_6Al_2 to (Si_6Al_2), change $Mg/(Mg + Fe^{+2}) = 0–0.7$, to $Mg/(Mg+Fe^{+2}) = 0–0.69$
74 **Heneuite,** add **73,** 440 (1988)
74 ***Henmilite,** $Ca_2Cu[B(OH)_4]_2(OH)_4$, tric., bluish-violet, **71,** 1234–1239 (1986)
74 ***Hentschelite,** $Cu^{+2}Fe_2^{+3}(PO_4)_2(OH)_2$, mon., dark green, *Lazulite* group, **72,** 404–408 (1987)
74 **Herderite,** add structurally related to the silicates of the *Gadolinite* group
75 **Hidalgoite,** change the formula to $PbAl_3(AsO_4)(SO_4)(OH)_6$
75 **Hilairite,** (after trig.), add compare **Calciohilairite**
76 ***Hingganite-(Ce),** $CeBeSiO_4(OH)$, mon., *Gadolinite* group
76 **Hiortdahlite,** change the formula to $(Ca,Na)_3(Zr,Ti,Y)Si_2O_7(O,OH,F)_2$
76 **Hochelagaite,** delete Can. Min. **24,** 449–453 (1986), replace by **72,** 1024 (1987)
76 **Hodgkinsonite,** change the formula to $MnZn_2SiO_4(OH)_2$
76 ***Holdawayite,** $Mn_6^{+2}(CO_3)_2(OH)_7(Cl,OH)$, mon., pink, **73,** 632–642 (1988)
77 Hongquiite, TiO, cub., **61,** 184–186 (1976), **71,** 228 (1976)
77 ***Howardevansite,** $NaCu^{+2}Fe_2^{+3}(VO_4)_3$, tric., black, **73,** 181–186 (1988)
77 **Howlite,** add **73,** 1138–1144 (1988)
77 **Huanghoite-(Ce),** change to **Huanghoite-(Ce),** (Huangheite)
78 Hühnerkobelite, change **Ferroalluaudite** to **Ferro-alluaudite**
78 **Hureaulite,** add compare **Sainfeldite, Villyaellenite**
78 **Hyalotekite,** in the formula, change CL to Cl
79 **Hydrodelhayelite,** add **72,** 1024 (1987)
79 Hydrogen autunite = **Chernikovite**
79 Hydroherderite, delete the hyphen in **Hydroxyl-herderite**
80 Hydromuscovite, Illite should not be in bold face
80 Hydrougrandite, should not be in bold face
80 ***Hydroxylbastnäsite-(La),** $(La,Ce)(CO_3)(OH,F)$, hex., **71,** 1277 (1986)
80 **Hydroxylbastnäsite-(Nd),** delete Min. Mag. **49,** 717–720 (1985); replace by **71,** 1277 (1986), **73,** 440–441 (1988)
80 **Hydroxylellestadite,** (after **Fluorellestadite**), insert compare **Chlorellestadite** and **Mattheddleite**
81 Hypersthene (should not be in bold face), an intermediate member of the series **Enstatite-Ferrosilite,** *Pyroxene* group
82 Illite, Brammallite should not be in bold face
82 **Ilmenite,** (after trig.), change to read forms two series, with **Geikielite,** and with **Pyrophanite,** *Ilmenite* group
82 **Ilvaite,** change the formula to $CaFe_2^{+2}Fe^{+3}Si_2O_7(O,OH)$
83 Imgreite, should not be in bold face
83 **Imiterite,** add **71,** 1277–1278 (1986)
83 **Imogolite,** change to $Al_2SiO_3(OH)_4$, **48,** 434 (1963), **54,** 50–71 (1969), **73,** 188 (1988)
83 **Incaite,** in the formula, change S_{13} to S_{15}
83 ***Ingersonite,** $Ca_3Mn^{+2}Sb_4^{+5}O_{14}$, hex., yellow, **73,** 405–412 (1988)
83 **Innelite,** change the formula to $(Ba,K)_4(Na,Ca)_3Ti_3(Si_2O_7)_2(SO_4)_2O_4$; (after tric.) add yellow-brown
84 **Iquiquieite,** change to **Iquiqueite**
84 **Iraqite,** change the formula to $K(La,Ce,Th)_2(Ca,Na)_4(Si,Al)_{16}O_{40}$
84 **Iridium,** change compare **Osmiridium** to compare **Osmiridium, Ruthenosmiridium**
84 **Iriginite,** change the formula to $U^{+6}(MoO_4)_2(OH)_2\cdot 3H_2O$
84 **Irtyshite,** add **71,** 1545 (1986)
84 ***Isocubanite,** $CuFe_2S_3$, cub., dimorph. with **Cubanite,** Min. Mag. **52,** 509–514 (1988)
85 **Izoklakeite,** change the formula to $Pb_{27}(Cu,Fe)_2(Sb,Bi)_{19}S_{57}$; add **72,** 222–223, 229 (1987)
86 **Jagoite,** change the formula to $Pb_3Fe^{+3}Si_4O_{12}(Cl,OH)$
86 **Jamesonite,** change compare **Benavidesite** to forms a series with **Benavidesite**
86 **Jaskolskiite,** in the formula change S_6 to S_5
87 Jeffersonite, delete **Acmite,** replace by **Diopside**
87 **Jinshajiangite,** change the reference to **69,** 567 (1984)
88 **Joesmithite,** change the formula to $PbCa_2(Mg,Fe^{+2},Fe^{+3})_5Si_6Be_2O_{22}(OH)_2$, (after black), add *Amphibole* group, add **73,** 843–844 (1988)
88 ***Johninnesite,** $Na_2Mg_4Mn_{12}^{+2}As_2^{+5}Si_{12}O_{43}(OH)_6$, tric., light yellow-brown, **73,** 928 (1988)
88 **Johnwalkite,** add **72,** 223 (1987)
88 **Jouravskite,** (after yellow), add *Ettringite* group
89 **Julgoldite-(Fe⁺²),** change forms a series with **Pumpellyite-(Fe⁺²)** to forms two series, with **Pumpellyite-(Fe⁺²)** and with **Pumpellyite-(Mg)**
90 ***Kadyrelite,** $Hg_4(Br,Cl)_2O$ (?), cub., orange, forms a series with **Eglestonite**
90 **Kalininite,** add **72,** 223 (1987)
91 ***Kamchatkite,** $KCu_3^{+2}OCl(SO_4)_2$, orth., greenish-brown to yellowish-brown
91 **Kamiokite,** add **73,** 191 (1988)
91 ***Kamotoite-(Y),** $(Y,Nd,Gd)_2U_4^{+6}(CO_3)_3O_{12}\cdot 14\tfrac{1}{2}H_2O$, mon., bright yellow, **73,** 191 (1988)
91 **Kanoite,** (after pinkish-brown), add dimorph with **Donpeacorite**

91 **Kashinite,** delete Min. Abs. 37, 236 (1986), replace by **72,** 223 (1987)
92 **Katoite,** (after x = 1.5–3), insert cub., change **70,** 437 (1985) to **70,** 873 (1985)
92 **Kawazulite,** (after trig.), add *Tetradymite* group
92 **Keivyite-(Y),** change to **Keiviite-(Y),** change **Keivyite-(Yb)** to **Keiviite-(Yb),** add **73,** 191–192 (1988)
92 **Keivyite-(Yb),** change to **Keiviite-(Yb),** change **Keivyite-(Y)** to **Keiviite-(Y)**
93 **Kennedyite,** delete the entire entry; change to Kennedyite (not bold face) = **Armalcolite** or **Pseudobrookite, 46,** 766 (1961), **73,** 1377–1383 (1988)
93 **Kentrolite,** change compare **Melanotekite** to forms a series with **Melanotekite**
93 **Kesterite,** (after group), insert compare **Ferrokesterite**
93 ***Keystoneite,** $(Ni,Mg,Fe,Mn)_3Te_3^{+4}O_9\cdot 5H_2O$, hex., golden-yellow
93 **Khademite,** delete compare **Rostite,** add **73,** 1499 (1988)
93 **Khanneshite,** (after **Burbankite**), add and **Remondite-(Ce)**
93 **Khatyrkite,** add **71,** 1278 (1986)
94 **Kimrobinsonite,** delete Can. Min. **23,** 573–576 (1985), replace by **72,** 1024 (1987)
94 **Kingsmountite,** replace compare **Montgomeryite** by *Montgomeryite* group
94 **Kirkite,** change to **Kirkiite,** add **71,** 1278–1279 (1986)
95 **Kitaibelite,** should not be in bold face, add Min. Mag. **52,** 726 (1988)
95 **Kivuite,** should not be in bold face
96 **Kolarite,** delete Can. Min. **23,** 501–506 (1985); replace by **71,** 1545 (1986)
96 ***Kombatite,** $Pb_{14}(VO_4)_2O_9Cl_4$, mon., bright yellow, compare **Sahlinite, 73,** 928 (1988)
98 Kularite, change **Monazite** to **Monazite-(Ce)**
98 **Kuliokite-(Y),** add **73,** 192 (1988)
99 ***Kuzminite,** $Hg_2(Br,Cl)_2$, tet., forms a series with **Calomel, 73,** 192 (1988)
101 **Laphamite,** delete Min. Mag. **50,** 279–282 (1986), replace by **73,** 1024–1025 (1987)
101 **Laueite,** change trimorph. with **Stewartite** and **Strunzite** to dimorph. with **Stewartite**
102 **Lavenite,** change the formula to $(Na,Ca)_2(Mn,Fe^{+2})(Zr,Ti)Si_2O_7(O,OH,F)$
102 **Lazulite,** delete compare **Barbosalite,** add *Lazulite* group
102 Lehiite (not bold face), delete the entire entry; replace with a mixture, **71,** 1515–1516 (1986)
102 **Leiteite,** add **72,** 629–632 (1987)
103 **Lengenbachite,** change mon. to tric., add **73,** 1426–1433 (1988)
104 **Likasite,** add **72,** 1028 (1987)
105 ***Lisetite,** $Na_2CaAl_4Si_4O_{16}$, orth., **71,** 1372–1383 (1986)
105 **Lonecreekite,** (after **Alum**), add and **Tschermigite**
106 ***Lourenswalsite,** $(K,Ba)_2(Ti,Mg)_4(Si,Al)_6O_{20}\cdot 6H_2O$, hex. (?), silver-gray, **73,** 1493–1494 (1988)
106 **Luanheite,** add **73,** 192–193 (1988)
106 ***Lucasite-(Ce),** $(Ce,La)Ti_2(O,OH)_6$, mon., dark brown, dimorph. with **Aeschynite-(Ce), 72,** 1006–1010 (1987)
106 ***Ludjibaite,** $Cu_5(PO_4)_2(OH)_4$, tric., blue-green, trimorph. with **Pseudomalachite** and **Reichenbachite, 73,** 1495 (1988)
107 ***Lyonsite,** $Cu_3^{+2}Fe_4^{+3}(VO_4)_6$, orth., black, **72,** 1000–1005 (1987)
108 **Maghagendorfite,** change the formula to $NaMgMn(Fe^{+2},Fe^{+3})_2(PO_4)_3$; delete compare **Alluaudite, Ferro-alluaudite, Hagendorfite**; replace by *Alluaudite* group
109 ***Magnesio-aubertite,** $(Mg,Cu)Al(SO_4)_2Cl\cdot 14H_2O$, tric., sky-blue, compare **Aubertite, Svyazhinite**
109 **Magnesiochloritoid,** add **73,** 358–364 (1988)
110 **Magnesiohastingsite,** in the formula, change Si_6Al_2 to (Si_6Al_2)
110 **Magnesiohulsite,** add **73,** 929 (1988)
110 **Magnesiosadanagaite,** in the formula, change (OH) to $(OH)_2$
111 ***Magnolite,** $Hg_2^{+1}Te^{+4}O_3$, orth.
111 **Mammothite,** change the formula to $Pb_6Cu_4AlSb^{+5}O_2(SO_4)_2Cl_4(OH)_{16}$; change the reference to **71,** 229–230, 1548 (1986)
112 ***Manganarsite,** $Mn_3^{+2}As_2^{+3}O_4(OH)_4$, trig. (?), pinkish-brown, **71,** 1517–1521 (1986)
112 **Manganberzeliite,** change yellow, to yellow to orange; after *Garnet* group, add and **Palenzonaite**
112 **Manganochromite,** (after cub.), add forms a series with **Vuorelainenite**
113 **Manganostibite,** add **73,** 167 (1988)
113 **Manganotapiolite,** delete compare **Staringite, Tapiolite;** replace by *Tapiolite* group
113 **Manganpyrosmalite,** delete compare **Pyrosmalite,** replace by dimorph. with **Brokenhillite,** forms a series with **Ferropyrosmalite,** add **73,** 933–934 (1988)
113 **Mannardite,** change the formula to $BaTi_6V_2^{+3}O_{16}\cdot H_2O$, add **73,** 193 (1988)
113 ***Maricopaite,** $Pb_7Ca_2(Si,Al)_{48}O_{100}\cdot 32H_2O$, orth., Can. Min. **26,** 309–313 (1988)
114 **Marsturite,** change the formula to $NaCaMn_3Si_5O_{14}(OH)$, add (after pink), compare **Nambulite, Natronambulite**
114 **Mathewrogersite,** add **72,** 1025 (1987)
114 ***Mattheddleite,** $Pb_{20}(SiO_4)_7(SO_4)_4Cl_4$, hex., compare **Chlorellestadite, 73,** 929 (1988)
115 ***Mcauslanite,** $HFe_3^{+2}Al_2(PO_4)_4F\cdot 18H_2O$, tric., yellowish-white, Can. Min. **26,** 917–921 (1988)
115 ***Mcbirneyite,** $Cu_3(VO_4)_2$, tric., black, **73,** 1495 (1988)
116 **Melanotekite,** change compare **Kentrolite** to forms a series with **Kentrolite**
116 **Melanovanadite,** change the formula to $CaV_2^{+4}V_2^{+5}O_{10}\cdot 5H_2O$, add **72,** 637–644 (1987)
116 **Mendozavilite,** add **73,** 193 (1988)
117 **Merlinoite,** in the formula, change $Si_{23}Al_9$ to $(Si_{25}Al_9)$
118 Metahaiweeite should not be in bold face
118 ***Metaswitzerite,** $Mn_3(PO_4)_2\cdot 4H_2O$, mon., pink to brown, **71,** 1221–1223 (1986)
119 **Metavivianite,** add **73,** 667 (1988)
120 **Minehillite,** in the formula, change $(OH)_4$ to $(OH)_{16}$
121 **Miserite,** change the formula to $K(Ca,Ce)_6Si_8O_{22}(OH,F)_2$
121 **Mitridatite,** change the formula to $Ca_2Fe_3^{+3}(PO_4)_3O_2\cdot 3H_2O$
122 **Monazite-(Nd),** add **73,** 1445 (1988)
122 **Mongolite,** add **71,** 1279 (1986)
122 Mongshanite, add **73,** 441 (1988)
122 Montdorite, should not be in bold face
123 **Monteregianite-(Y),** change orth. to mon.; add **72,** 365–374 (1987)
123 **Montgomeryite,** change compare **Kingsmountite** to *Montgomeryite* group
123 **Montroyalite,** delete Can. Min. **24,** 455–459 (1986), replace by **72,** 1025 (1987)
123 **Moolooite,** delete Min. Mag. **50,** 295–298 (1986), replace by **72,** 1025–1026 (1987)
124 **Mosandrite,** change the formula to $(Na,Ca,Ce)_3TiSi_2O_7(F,OH,O)_2$
124 **Mosesite,** change the formula to $Hg_2N(Cl,SO_4,MoO_4,CO_3)\cdot H_2O$
125 ***Moydite-(Y),** $YB(OH)_4(CO_3)$, orth., yellow, **73,** 193–194 (1988)
125 **Mukhinite,** in the formula change V to V^{+3}

125 **Munirite,** change the formula to $NaVO_3\cdot(2\text{-}x)H_2O$, change orth. to mon., add Min. Mag. **52,** 716–717 (1988)

126 **Nabaphite,** change the formula to $NaBaPO_4\cdot 9H_2O$

126 ***Nabokoite,** $Cu_7^{+2}Te^{+4}O_4(SO_4)_5\cdot KCl$, tet., yellow-brown, forms a series with **Atlasovite, 73,** 929 (1988)

126 **Nambulite,** (after **Natronambulite**), add compare **Marsturite**

127 **Nasonite,** delete compare **Ganomalite**

127 **Natalyite,** add **72,** 223–224 (1987)

128 **Natronambulite,** (after **Nambulite**), add compare **Marsturite, 72,** 223–224 (1987)

128 **Nekoite,** change the formula to $Ca_3Si_6O_{15}\cdot 7H_2O$

128 Nenadkevichite, should not be in bold face

129 ***Nickelaustinite,** Ca(Ni,Zn)(AsO_4)(OH), orth., yellow-green to grass green, *Adelite group*, **73,** 930 (1988)

130 Change **Niobo-aeschynite (Nd)** to **Niobo-aeschynite-(Nd)**

131 **Northupite,** (after **Tychite**), add and **Ferrotychite**

133 **Obradovicite,** change the formula to $H_4(K,Na)Cu^{+2}Fe_2^{+3}(AsO_4)(MoO_4)_5\cdot 12H_2O$, delete Min. Mag. **50,** 283–284 (1986), add **72,** 1026 (1987)

133 **O'Danielite,** change the formula to $Na(Zn,Mg)_3H_2(AsO_4)_3$

133 **Ogdensburgite,** change the entry to $Ca_2(Zn,Mn)Fe_4^{+3}(AsO_4)_4(OH)_6\cdot 6H_2O$, orth., ps. hex., brownish-red, **67,** 858 (1982), **72,** 409–412 (1987)

133 **Ojuelaite,** delete compare **Arthurite, Earlshannonite, Whitmoreite,** replace by *Arthurite* group

133 **Okenite,** change the formula to $Ca_5Si_9O_{23}\cdot 9H_2O$

133 ***Okhotskite,** $Ca_8(Mn^{+2},Mg)_4(Mn^{+3},Al,Fe^{+3})_8Si_{12}O_{46}(OH)_{12}$, mon., deep orange, *Pumpellyite* group, **73,** 1495–1496 (1988)

133 **Olenite,** add **73,** 441 (1988)

134 **Omphacite,** replace the entry by a clinopyroxene, a solid solution of **Augite** (Aug), **Jadeite** (Jd), and **Aegirine** (Aeg), with the composition range $Jd_{75\text{-}25}Aug_{25\text{-}75}Aeg_{0\text{-}25}$, *Pyroxene* group

134 **Ordonezite,** delete **compare Byströmite,** replace by *Tapiolite* group

134 ***Örebroite,** $Mn_3^{+2}(Sb^{+5},Fe^{+3})Si(O,OH)_7$, hex., dark brown, compare **Franciscanite, Welinite, 71,** 1522–1526 (1986)

134 Orthite, change **Allanite** to **Allanite-(Ce)**

135 **Orthoferrosilite,** delete the entire entry, replace by Orthoferrosilite = **Ferrosilite**

135 **Orthopinakiolite,** add (after **Takeuchiite**), compare **Blatterite**

135 **Orthoserpierite,** add **72,** 1026 (1987)

135 **Osarsite,** delete compare **Ruarsite**

136 **Otjisumeite,** add **72,** 1026–1027 (1987)

136 Oyelite, change to **Oyelite**

137 **Paderaite,** add **72,** 224 (1987)

137 ***Pahasapaite,** $(Ca,Li,K,Na)_{27}Li_{16}Be_{48}(PO_4)_{48}\cdot 76H_2O$, cub., **73,** 1496 (1988)

137 ***Palenzonaite,** $(Ca,Na)_3Mn^{+2}(V^{+5},As^{+5},Si)_3O_{12}$, cub., wine-red, structurally related to the *Garnet* group and **Berzeliite** and **Manganberzeliite, 73,** 930 (1988)

137 **Panunzite,** add **73,** 420–421 (1988)

138 **Parabariomicrolite,** add **73,** 194 (1988)

138 ***Parabrandtite,** $Ca_2Mn^{+2}(AsO_4)\cdot 2H_2O$, tric., dimorph. with **Brandtite,** *Fairfieldite* group, **73,** 1496 (1988)

139 **Paramendozavilite,** add **73,** 194 (1988)

139 ***Paraotwayite,** $Ni(OH)_{2\text{-}x}(SO_4,CO_3)_{0.5x}$, x~0.6, mon., fibrous, green, **73,** 1496 (1988)

140 **Parisite-(Nd),** add **73,** 1496–1497 (1988)

140 **Paulingite,** change the formula to $(K_2,Ca,Na_2,Ba)_5Al_{10}Si_{35}O_{90}\cdot 45H_2O$

140 ***Paulkellerite,** $Bi_2Fe^{+3}(PO_4)O_2(OH)_2$, mon., light greenish-yellow, **73,** 870–875 (1988)

140 **Paulkerrite,** in the formula, change $10H_2O$ to $15H_2O$

142 ***Perroudite,** $Hg_{5\text{-}x}Ag_{4+x}S_{5\text{-}x}(Cl,I,Br)_{4+x}$, orth., bright red, **72,** 1251–1256 (1987)

142 ***Petedunnite,** $Ca(Zn,Mn,Mg,Fe)Si_2O_6$, mon., dark green, *Pyroxene* group, **72,** 157–166 (1987)

142 ***Petrukite,** $(Cu,Fe,Zn)_2(Sn,In)S_4$, orth.

143 **Philipsburgite,** delete Can. Min. **23,** 255–258 (1985), replace by **71,** 1279 (1986)

144 **Pinakiolite,** change the formula to $(Mg,Mn^{+2})_2(Mn^{+3},Sb^{+3})BO_5$

145 **Plattnerite,** (after tet.) add dimorph. with **Scrutinyite**

146 Plumalsite should not be in bold face

146 **Pokrovskite,** (after group), add and **Malachite**

146 **Polhemusite,** (after tet.), insert ps. cub.

147 ***Ponomarevite,** $K_4Cu_4^{+2}OCl_{10}$, mon., orange-red

147 **Potassium Alum,** (after **Lonecreekite**), add and **Tschermigite**

147 ***Pottsite,** $PbBiH(VO_4)_2\cdot 2H_2O$, tet., yellow, Min. Mag. **52,** 389–390 (1988)

147 ***Poudretteite,** $KNa_2B_3Si_{12}O_{30}$, hex., *Osumilite* group, **73,** 1496 (1988)

148 **Protasite,** delete Min. Mag. **50,** 125–128 (1986), replace by **72,** 225, 1230–1238 (1987)

148 **Pseudobrookite,** change the formula to $(Fe^{+3},Fe^{+2})_2(Fe^{+3},Ti)O_5$, delete **Kennedyite**

149 **Pseudomalachite,** change the formula to $Cu_5(PO_4)_2(OH)_4$, add (after green), trimorph. with **Ludjibaite** and **Reichenbachite**

149 Pseudowollastonite (not bold face), change **Wollastonite** to **Wollastonite-1T**

150 **Pyrophanite,** delete compare **Geikielite** and **Ilmenite;** replace (after brownish-red) by forms a series with **Ilmenite,** *Ilmenite* group

150 Pyrosmalite (not bold face), delete the present entry; replace by any member of the series **Ferropyrosmalite-Manganpyrosmalite**

151 **Qandilite,** delete Min. Mag. **49,** 739–744 (1985); replace by **73,** 930 (1988)

151 **Qitianglinite,** add Min. Abs. **38,** no. 2, p. 349 (1987)

152 **Radhakrishnaite,** change the formula to $PbTe_3(Cl,S)_2$, delete Can. Min. **23,** 501–506 (1985), replace by **71,** 1545–1546 (1986)

152 **Raite,** change the formula to $Na_4Mn_3Si_8(O,OH)_{24}\cdot 9H_2O$

152 **Ramsbeckite,** change the formula to $(Cu,Zn)_{15}(SO_4)_4(OH)_{22}\cdot 6H_2O$, add **72,** 225 (1987)

152 **Rankachite,** in the formula, change $6H_2O$ to $12H_2O$

153 **Rapidcreekite,** delete Can. Min. **24,** 51 (1986), replace by **72,** 225 (1987)

153 **Redledgeite,** change the formula to $BaTi_6Cr_2^{+3}O_{16}\cdot H_2O$, add **73,** 196 (1988)

153 ***Reichenbachite,** $Cu_5^{+2}(PO_4)_2(OH)_4$, mon., dark green, trimorph. with **Ludjibaite** and **Pseudomalachite, 72,** 404–405 (1987)

154 ***Remondite-(Ce),** $Na_3(Ce,La,Ca,Na,Sr)_3(CO_3)_5$, mon., ps. hex., red-orange, compare **Burbankite, Khanneshite**

154 **Reyerite,** add Min. Mag. **52,** 247–256 (1988)

154 **Rhabdophane-(Nd),** the second rhabdophane is misspelled

154 Rhenium, should not be in bold face

154 **Rhodizite,** in the formula, replace (Ca,K) by (K,Cs); add **72,** 1028 (1987)

155 ***Ribbeite,** $(Mn^{+2},Mg)_5(SiO_4)_2(OH)_2$, orth., dimorph. with **Alleghanyite,** *Humite* group, **72,** 213–216 (1987)

156 Roentgenite, change **Röntgenite** to **Röntgenite-(Ce)**

156 **Roggianite,** change the formula to $(Ca,Na,K)_{15}Al_{15}Be_3Si_{28}O_{90}(OH)_{16}\cdot 34H_2O$, add Min. Mag. **52,** 201–206 (1988)
156 **Romanechite,** change the formula to $(Ba,H_2O)(Mn^{+4},Mn^{+3})_5O_{10}$, add **73,** 1155–1161 (1988)
157 **Roselite,** delete compare **Brandtite;** replace by *Roselite* group
157 **Rosemaryite,** change 65, 811 (1980) to **65,** 810–811 (1980)
157 Rostite (not bold face), delete the entire entry, replace by Rostite = **Khademite, 73,** 497)1988)
157 **Roubaultite,** change the formula to $Cu_2(UO_2)_3(CO_3)_2O_2(OH)_2\cdot 4H_2O$
158 ***Roxbyite,** Cu_9S_5, mon., Min. Mag. **52,** 323–330 (1988)
158 **Ruarsite,** delete compare **Osarsite**
158 **Ruizite,** change the formula to $CaMn^{+3}Si_2O_6(OH)\cdot 2H_2O$
158 **Ruthenosmiridium,** change compare **Osmiridium** to compare **Iridium, Osmiridium**
159 **Sabieite,** change hex. to trig.
159 **Sahamalite,** change to **Sahamalite-(Ce)**
159 **Sahlinite,** add compare **Kombatite**
159 **Sainfeldite,** change the formula to $Ca_5(AsO_4)_2[AsO_3(OH)]_2\cdot 4H_2O$, add compare **Hureaulite, Villyaellenite**
159 **Sakuraiite,** change the formula to (Cu,Zn,Fe,In,Sn)S, add **73,** 934 (1988)
160 **Santafeite,** add **72,** 1028 (1987)
161 **Sarcolite,** change the formula to $NaCa_6Al_4Si_6O_{24}F$ (?), delete **69,** 158 (1984), add **70,** 441 (1985)
161 **Sayrite,** in the formula, change Pb to Pb_2
162 Schefferite, change **Acmite** to **Aegirine**
162 Scheteligite should not be in bold face
162 **Schlossmacherite,** change the formula to $(H_3O,Ca)Al_3(AsO_4,SO_4)_2(OH)_6$
162 **Schmiederite,** change the formula to $Pb_2Cu_2(Se^{+6}O_4)(Se^{+4}O_3)(OH)_4$, delete the (?) after mon., delete Min. Mag. **43,** 824 (1980) and replace by **73,** 199 (1988)
162 **Schneiderhöhnite,** change the formula to $Fe^{+2}Fe_3^{+3}As_5^{+3}O_{13}$, add **72,** 1028 (1987)
163 **Schöllhornite,** change the formula to $Na_{0.3}CrS_2\cdot H_2O$
163 **Scholzite,** change the reference to **66,** 843–851 (1981)
164 **Scorzalite,** delete compare **Barbosalite,** (after **Lazulite**), add *Lazulite* group
164 ***Scrutinyite,** alpha-PbO_2, orth., dimorph. with **Plattnerite,** dark reddish-brown, Can. Min. **26,** 905–910 (1988)
164 **Selenostephanite,** add **72,** 225 (1987)
165 Selen-tellurium should not be in bold face
166 **Shakhovite** (Shahovite), change the formula to $Hg_4^{+1}Sb^{+5}O_3(OH)_3$, add **68,** 1041 (1983), **73,** 1499 (1988)
166 **Shigaite,** add **71,** 1546 (1986)
167 **Sidwillite,** add **71,** 1546 (1986)
167 ***Sieleckiite,** $Cu_3Al_4(PO_4)_2(OH)_{12}\cdot 2H_2O$, tric., blue, Min. Mag. **52,** 515–518 (1988)
167 **Sigloite,** change the formula to $Fe^{+3}Al_2(PO_4)_2(OH)_3\cdot 5H_2O$
167 **Simonkolleite,** add **73,** 194–195 (1988)
167 **Sincosite,** change mon., ps. tet. to tet., add **70,** 409–410 (1985)
167 **Sinjarite,** (after the formula), add tet.
168 ***Skippenite,** $Bi_2Se_2(Te,S)$, trig., **Tetradymite** group, Can. Min. **25,** 625–640 (1987)
168 **Slawsonite,** add **72,** 225–226 (1987)
168 **Smolianinovite,** (after orth.), add compare **Fahleite**
169 Sobotkite (not bold face), delete the entry, replace by = aluminian **Saponite** (?), **61,** 177 (1976)
169 **Sodium anthophyllite,** in the formula, replace Si_7Al by (Si_7Al)
169 Sodium phlogopite should not be in bold face
170 **Sogdianite,** change the formula to $(K,Na)_2(Li,Fe^{+3},Al)_3ZrSi_{12}O_{30}$
170 **Sorensenite,** change the formula to $Na_4SnBe_2Si_6O_{18}\cdot 2H_2O$
171 **Sphenisciditë,** delete Min. Mag. **50,** 291–293 (1986), replace by **72,** 1027 (1987)
171 **Srebrodolskite,** add compare **Brownmillerite, 71,** 1279–1280 (1986)
171 **Stannite,** (after tet.), add dimorph. with **Ferrokesterite**
171 **Stannomicrolite,** change the formula to $(Sn^{+2},Fe^{+2})(Ta,Nb,Sn^{+4})_2(O,OH)_7$
171 **Staringite,** delete compare **Manganotapiolite, Tapiolite,** replace by *Tapiolite* group
172 **Steenstrupine-(Ce),** change the formula to $Na_{14}Ce_6Mn^{+2}Mn^{+3}Fe_3^{+2}Zr(Si_6O_{18})_2(PO_4)_7(OH)_2\cdot 3H_2O$
172 **Stewartite,** delete trimorph. with **Laueite** and **Strunzite,** replace by dimorph. with **Laueite**
173 ***Stibiomicrolite,** $(Sb,Ca,Na)_2(Ta,Nb)_2(O,OH)_7$, *Pyrochlore* group, **73,** 1499 (1988)
173 **Stilpnomelane,** change the formula to $K(Fe^{+2},Mg,Fe^{+3},Al)_8(Si,Al)_{12}(O,OH)_{27}\cdot 2H_2O$
173 **Stottite,** add **73,** 657–661 (1988)
174 ***Stronalsite,** $SrNa_2Al_4Si_4O_{16}$, orth., *Feldspar* group, compare **Banalsite, 72,** 226 (1987), **73,** 195 (1988)
174 Strontiohilgardite (not bold face), change the entry to = strontian **Tyretskite, 44,** 1152 (1959)
174 ***Strontiopyrochlore,** $Sr_2Nb_2(O,OH)_7$, cub., *Pyrochlore* group, **73,** 930 (1988)
175 **Strunzite,** in the formula, change $8H_2O$ to $6H_2O$, delete trimorph. with **Laueite** and **Stewartite,** change compare **Ferrostrunzite** to compare **Ferristrunzite** and **Ferrostrunzite**
175 **Sturmanite,** delete Can. Min. **21,** 705–709 (1983), replace by **73,** 195 (1988)
175 **Sugilite,** change the formula to $KNa_2(Fe^{+2},Mn^{+2},Al)_2Li_3Si_{12}O_{30}$
176 Sundiusite, should not be in bold face
176 Svetlozarite, in the ref., change Min. Mag. **46,** to **45**
176 **Svyazhinite,** (after **Aubertite**) add and **Magnesioaubertite**
177 **Sweetite,** delete dimorph with **Wülfingite,** replace by trimorph. with **Ashoverite** and **Wülfingite**
177 **Swinefordite,** change the formula to $(Ca,Na)_{0.3}(Al,Li,Mg)_2(Si,Al)_4O_{10}(OH,F)_2\cdot 2H_2O$
177 **Switzerite,** change the entry to $(Mn^{+2},Fe^{+2})_3(PO_4)_2\cdot 7H_2O$, mon., pink to brown, **52,** 1595–1602 (1967), **71,** 1221–1223 (1986)
177 Sztrokayite (not bold face), add **72,** 1027 (1987)
178 **Tacharanite,** in the first reference, change 1952 to 1962
178 **Taikanite,** add **72,** 226 (1987)
178 **Takeuchiite,** (after **Pinakiolite**), add compare **Blatterite**
178 **Talmessite,** (after **Gaitite**), add *Fairfieldite* group
179 **Taranakite,** change the formula to $H_7K_2(Al,Fe^{+3})_5(PO_4)_8\cdot 20H_2O$ (?)
179 **Tapiolite,** delete compare **Manganotapiolite, Staringite,** replace by *Tapiolite* group
180 **Tellurantimony,** change compare **Tellurobismuthite** to forms a series with **Tellurobismuthite,** add *Tetradymite* group
180 **Tellurobismuthite,** change compare **Tellurantimony,** to forms a series with **Tellurantimony,** *Tetradymite* group
180 *Tengchongite, $CaU_6^{+6}Mo_2^{+6}O_{25}\cdot 12H_2O$, orth., yellow, **73,** 195–196 (1988)
181 **Tetradymite,** add *Tetradymite* group

181 **Thalenite-(Y),** change the formula to $Y_3Si_3O_{10}(F,OH)$

182 **Thometzekite,** add **73,** 931 (1988)

182 **Thorite,** change the formula to $(Th,U)SiO_4$

182 ***Thornasite,** $(Na,K)ThSi_{11}(O,F,OH)_{25} \cdot 8H_2O$, trig., **73,** 931 (1988)

182 **Thortveitite,** change **Kievyite-(Y)** to **Kieviite-(Y)** and **Keivyite-(Yb)** to **Kieviite-(Yb),** add **73,** 601–607 (1988)

183 **Tikhonenkovite,** add dimorph. with **Acuminite**

183 **Tinticite,** change the formula to $Fe_4^{+3}(PO_4)_3(OH)_3 \cdot 5H_2O$

183 **Tiptopite,** change the formula to $K_2(Na,Ca)_2Li_3Be_6(PO_4)_6(OH)_2 \cdot H_2O$, add **72,** 816–820 (1987)

184 **Tokkoite,** in the formula, change K_4 to K_2, add **73,** 196 (1988)

185 ***Törnebohmite-(La),** $(La,Ce)_2Al(SiO_4)_2(OH)$, mon.

185 ***Trabzonite,** $Ca_4Si_3O_{10} \cdot 2H_2O$, mon., **73,** 1497 (1988)

185 **Tschermigite,** add compare **Lonecreekite, Potassium alum**

187 **Tugarinovite,** add **73,** 199 (1988)

188 Turgite, change absorbed to adsorbed

188 **Turneaureite,** delete Can. Min. **23,** 251–254 (1985), replace by **71,** 1280 (1986)

188 **Turquoise,** in the formula, change $5H_2O$ to $4H_2O$

189 Ugrandite, delete **Hydrogrossular,** replace by **Hibschite, Katoite;** correct the spelling of **Schorlomite**

189 Ungursaite, should not be in bold face; add = sodian **Calciotantite** (?), add **71,** 1546–1547 (1986)

190 **Uralolite,** change the formula to $Ca_2Be_4(PO_4)_3(OH)_3 \cdot 5H_2O$, add Min. Record **9,** 99–100 (1978)

190 **Uranophane** and **Uranophane-beta,** change both formulas to $Ca(UO_2)SiO_3(OH)_2 \cdot 5H_2O$

190 **Uranotungstite,** change the entry to $(Ba,Pb,Fe^{+2})(UO_2)_2WO_4(OH)_4 \cdot 12H_2O$, orth., yellow to orange, **71,** 1547 (1986)

191 Change **Usonite** to **Uzonite,** delete Min. Abs. **37,** 240 (1986), replace by **71,** 1280 (1986)

192 ***Vantasselite,** $Al_4(PO_4)_3(OH)_3 \cdot 9H_2O$, orth., **73,** 931 (1988)

192 **Vanuralite,** change the formula to $Al(UO_2)_2V_2O_8(OH) \cdot 11H_2O$

192 Vanuranylite should not be in bold face

192 **Varulite,** in the formula, change (Na,Ca) to NaCa; (after **Hagendorfite**), add *Alluaudite* group

193 **Vauxite,** delete compare **Gordonite**

193 Velikite (not bold face), Cu_2HgSnS_4, tet., *Stannite* group, **62,** 1260 (1977)

193 Verdelite, change to a green mineral of the *Tourmaline* group

194 **Villyaellenite,** change the formula to $(Mn,Ca,Zn)_5(AsO_4)_2(AsO_3OH)_2 \cdot 4H_2O$; add compare **Hureaulite, Sainfeldite, 71,** 1547 (1986), **73,** 1172–1178 (1988)

194 **Vinciennite,** delete Min. Abs. **37,** 99 (1986), replace by **71,** 1280–1281 (1986)

194 **Viseite,** change the formula to $Ca_{10}Al_{24}(SiO_4)_6(PO_4)_7O_{22}F_3 \cdot 72H_2O$ (?)

194 **Vismirnovite,** in the reference, change 1079 to 1077

195 **Volborthite,** change the formula to $Cu_3V_2O_7(OH)_2 \cdot 2H_2O$

195 ***Volfsonite,** $Cu_{10}^{+1}Cu^{+2}Fe^{+2}Fe_2^{+3}Sn_3^{+4}S_{16}$, hex., **73,** 441 (1988)

195 **Volkonskoite,** add **73,** 934 (1988)

195 **Vuonnemite,** change the formula to $Na_5Nb_2Ti^{+3}(Si_2O_7)_2O_2F_2 \cdot 2Na_3PO_4$

195 **Vuorelainenite,** (after cub.), add forms a series with **Manganochromite**

196 **Wadeite,** change the formula to $(K,Na)_2ZrSi_3O_9$

196 **Wakefieldite-(Ce),** add **73,** 934 (1988)

197 ***Watkinsonite,** $PbCu_2Bi_4(Se,S)_8$, mon., Can. Min. **25,** 625–635 (1987)

197 **Waylandite,** add **73,** 199 (1988)

197 **Weibullite,** change the formula to $(Pb,Ag)_6Bi_8(S,Se)_{18}$

197 Weilerite, should not be in bold face

197 **Weishanite,** add **73,** 196 (1988)

197 **Welinite,** change the entry to $Mn_3(W,Mg)_2Si(O,OH)_4$, hex., compare **Franciscanite, Örebroite, 53,** 1064 (1978), **71,** 1522–1526 (1986)

197 ***Wendwilsonite,** $Ca_2(Mg,Co)(AsO_4)_2 \cdot 2H_2O$, mon., pink, forms a series with **Roselite,** *Roselite* group, **72,** 217–221 (1987)

198 **Wermlandite,** change the formula to $Ca_2Mg_{14}(Fe^{+3},Al)_4(CO_3)(OH)_{42} \cdot 14\text{–}15H_2O$

198 ***Wheatleyite,** $Na_2Cu(C_2O_4)_2 \cdot 2H_2O$ (an oxalate), tric., blue, **71,** 1240–1242 (1986)

198 **Whitmoreite,** delete compare **Arthurite, Earlshannonite, Ojuelaite,** replace by *Arthurite* group

199 **Willhendersonite,** correct the spelling and move to follow **Willemseite**

199 **Wöhlerite,** change the formula to $NaCa_2(Zr,Nb)Si_2O_7(O,OH,F)_2$

200 **Wülfingite,** add **73,** 196–197 (1988), delete dimorph. with **Sweetite,** replace by trimorph. with **Ashoverite** and **Sweetite**

201 **Xenotime-(Y),** change **Chernovite** to **Chernovite-(Y),** change **Wakefieldite** to **Wakefieldite-(Y)**

201 **Xilingoite,** change to **Xilingolite**

201 **Xinganite-(Y)** should not be in bold face. Change the entry to read Xinganite-(Y) = **Hingganite-(Y)**

202 ***Yakhontovite,** $(Ca,Na)_{0.3}(Cu,Fe^{+2},Mg)_2Si_4O_{10}(OH)_2 \cdot 3H_2O$, mon., pistachio-green, *Smectite* group

202 **Yeatmanite,** change the formula to $Mn_9^{+2}Zn_6Sb_2^{+5}Si_4O_{28}$

202 **Yecoraite,** add **71,** 1547 (1986)

202 **Ye'elimite,** delete Min. Abs. **36,** 487 (1985), replace by **72,** 226 –227 (1987)

202 Yftisite-(Y) should not be in bold face

202 *Yttroceberysite = **Hingganite-(Y), 73,** 442 (1988)

203 **Yttrotantalite-(Y),** (after orth.), add dimorph. with **Formanite-(Y)**

203 **Yukonite,** change the formula to $Ca_2Fe_3^{+3}(AsO_4)_4(OH) \cdot 12H_2O$ (?)

203 **Yuksporite,** add **71,** 1547–1548 (1986)

204 ***Zharchikhite,** $AlF(OH)_2$, mon., twinned

204 **Ziesite,** change $Cu_2V_2^{+5}O_7$ to beta-$Cu_2V_2^{+5}O_7$, (after black), add dimorph. with **Blossite**

204 **Zimbabweite,** change the formula to $Na(Pb,K,Na)_2As_4(Ta,Nb,Ti)_4O_{18}$, add **73,** 1186–1190 (1988)

205 **Zincobotryogen,** (after mon.), add orange-red

205 ***Zincochromite,** $ZnCr_2O_4$, cub., brownish-black, *Spinel* group, **73,** 931–932 (1988)

205 ***Zincroselite,** $Ca_2Zn(AsO_4)_2 \cdot 2H_2O$, mon., dimorph. with **Gaitite,** *Roselite* group, **73,** 932 (1988)

206 ***Zodacite,** $Ca_4Mn^{+2}Fe_4^{+3}(PO_4)_6(OH)_4 \cdot 12H_2O$, mon., yellow, *Montgomeryite* group, **73,** 1179–1181 (1988)

206 **Zorite,** change the formula to $Na_6(Ti,Nb)_2(Si_6O_{17})_2(O,OH) \cdot 11H_2O$ (?)

206 **Zoubekite,** add **72,** 227 (1987)

207 Adelite group: change to read B = Co, Cu, Fe^{+2}, Mg, Ni, Zn; add Cobaltaustinite, Nickelaustinite. The list of minerals should read

Adelite
Austinite
Calciumvolborthite
Cobaltaustinite
Conichalcite
Duftite
Gabrielsonite
Nickelaustinite

207 Aenigmatite group: the list of minerals should be
Aenigmatite
Dorrite
Krinovite
Rhönite
Serendibite
Welshite

207 Add: Alluaudite group
Monoclinic phosphates and arsenates of general formula $NaABC_2(XO_4)_3$, $A = Ca, Mg, Pb$; $B = Fe^{+2}, Mn^{+2}$; $C = Mn^{+2}, Fe^{+2}, Fe^{+3}, Mg$; $X = P, As$
Alluaudite
Arseniopleite
Caryinite
Ferro-alluaudite
Hagendorfite
Maghagendorfite
Varulite

207 Alunite group: in the general formula, change $(OH)_2$ to $(OH)_{12}$; in the list of minerals, add Ammonioalunite

207 Amphibole group: change to $A = Ca, Na, K, Pb$; change to $Z = Al, Be, Si, Ti$. On p. 208, in the list of minerals, add Joesmithite

208 Apatite group: change the first sentence to Hexagonal phosphates, arsenates, etc. Change the last sentence to read Britholite-(Ce), Britholite-(Y), Chlorellestadite, Fluorellestadite, Hydroxylellestadite, and Mattheddleite are silicates, and Cesanite is a sulfate; all these minerals are isostructural with the minerals of the Apatite group

209 Add: Arthurite group
Monoclinic arsenates and phosphates of general formula $M^{+2}Fe_2^{+3}(XO_4)_2(O,OH)_2\cdot 4H_2O$, $M^{+2} = Cu, Fe, Mn, Zn$; $X = As, P, S$
Arthurite
Earlshannonite
Ojuelaite
Whitmoreite

209 Astrophyllite group: change Magnesiumastrophyllite to Magnesium astrophyllite

209 Autunite group: Fritzcheite is misspelled; delete Uranite

210 Beudantite group: change $X = As, P$ to $X = As^{+5}, P^{+5}$

210 Brackebuschite group: (in the B list), replace Mn by Mn^{+2}, Mn^{+3}

210 Calcite group: replace Sphaerocobaltite by Spherocobaltite

211 Chlorite group: change monoclinic to monoclinic or triclinic; change $A = Al, Fe^{+2}, Fe^{+3}, Li, Mg, Mn^{+2}, Ni$; by adding (after Ni), Zn; add Baileychlore as the first in the list of minerals; at the end of the list, add compare Franklinfurnaceite

212 Copiapite group: change $B^{+3}Fe_4^{+3}(SO_4)_6O(OH)\cdot 20H_2O$ to $B^{+3}_{2/3}Fe_4^{+3}(SO_4)_6O(OH)\cdot 20H_2O$

212 Crandallite group: add Arsenoflorencite-(Ce)

212 Crichtonite group: change trigonal oxides to trigonal or monoclinic, pseudo-trigonal oxides; add Davidite-(Ce)

212 Add: Datolite group = Gadolinite group

213 Epidote group: (after formula), change $A_2B_3(SiO_4)_3(OH)$ to $A_2B_3Si_3O_{12}(OH)$ or $A_2B_3Si_3O_{11}(OH,F)_2$, change Allanite to Allanite-(Ce), add Dollaseite-(Ce)

213 Ettringite group: (after H_2O), change to $X = Al, Cr^{+3}, Fe^{+3}, Mn^{+2}, Mn^{+4}, Si$; $Y = (SO_4,CO_3)_3$ or $(SO_4)_2B(OH)_4$

213 Fairfieldite group: mineral list should read
Cassidyite
Collinsite
Fairfieldite
Gaitite
Messelite
Parabrandtite
Roselite-beta
Talmessite

213 Feldspar group: add Stronalsite

214 Gadolinite group: the list of minerals should read
Bakerite
Datolite
Gadolinite-(Ce)
Gadolinity-(Y)
Hingganite-(Ce)
Hingganite-(Y)
Hingganite-(Yb)
Homilite
Minasgeraisite-(Y)

Add the phosphates Drugmanite and Herderite are structurally related to the minerals of this group

214 Garnet group: (after the list of minerals) change to The arsenates Berzeliite and Manganberzeliite, the vanadate Palenzonaite, and the halide Cryolithionite are isostructural with the minerals of the Garnet group; Henritermierite is a related mineral

215 Humite group: in the list of minerals, add Ribbeite

215 Add: Ilmenite group
Trigonal oxides of general formula $M^{+2}TiO_3$, $M^{+2} = Fe, Mg, Mn, Zn$
Ecandrewsite
Geikielite
Ilmenite
Pyrophanite

216 Kaolinite-Serpentine group: (after Silicates), add tric.

216 Add: Lazulite group
Monoclinic phosphates of general formula $A^{+2}B_2^{+3}(PO_4)_2(OH)_2$, $A = Cu, Fe, Mg$; $B = Al, Fe$
Barbosalite
Hentschelite
Lazulite
Scorzalite

217 Ludwigite group: change to read $Y = Al, Fe^{+3}, Mg, Mn^{+3}, Sb^{+5}, Ti$; add Chestermanite

218 Melonite group: change Berndtite to Berndtite-C6

218 Meta-autunite group: (after Fe^{+2}), insert $(H_3O)_2$; in the list of minerals, add Chernikovite

219 Mica group: (after the list of minerals), add compare Brammallite, Illite, Rectorite

219 Monazite group: in the list of minerals, add Gasparite-(Ce)

219 Add: Montgomeryite group
Monoclinic phosphates of general formula $Ca_4A^{+2}B_4^{+3}(PO_4)_6(OH)_4\cdot 12H_2O$, $A^{+2} = Fe, Mg, Mn$; $B^{+3} = Al, Fe$
Calcioferrite
Kingsmountite
Montgomeryite
Zodacite

220 Osumilite group: change to $C = Al, B, Be, Fe^{+2}, Fe^{+3}, Li, Mg$; in the list of minerals, add Poudretteite

221 Add: Plumbogummite group = Crandallite group

221 Pumpellyite group: change to read $X = Al, Fe^{+2}, Fe^{+3}, Mg, Mn^{+2}$; $Y = Al, Fe^{+3}, Cr^{+3}, Mn^{+3}$; the list of minerals should read
Julgoldite-(Fe^{+2})
Okhotskite
Pumpellite-(Fe^{+2})
Pumpellyite-(Mg)
Pumpellyite-(Mn^{+2})
Shuiskite

222 Pyrochlore group: change to read $B = Fe, Nb, Sn, Ta, Ti, W$; the last part of the list of minerals should read
Stibiobetafite
Stibiomicrolite
Strontiopyrochlore
Uranmicrolite
Uranpyrochlore
Yttrobetafite-(Y)
Yttropyrochlore-(Y)

(after the mineral list) change to read Ferritungstite (cub.), Jixianite (cub.), and Zirkelite (mon.) are structurally related oxides; Ralstonite is an isostructural halide. The nomenclature of this group is discussed in **62,** 403–410 (1977), with the recommendation of the I.M.A. Commission on New Minerals and Mineral Names.

223 Pyroxene group: (in the list A =), change $Mn^{+}2$ to Mn^{+2}; the list of minerals should now read
Aegirine
Augite
Clinoenstatite
Clinoferrosilite
Diopside
Donpeacorite
Enstatite
Esseneite
Ferrosilite
Hedenbergite
Hypersthene
Jadeite
Jervisite
Johannsenite
Kanoite
Kosmochlor
Natalyite
Omphacite
Petedunnite
Pigeonite
Spodumene

(after the list of minerals), add The nomenclature of the Pyroxene group has been revised to accord with the recommendation published by the Commission on New Minerals and Mineral Names, I.M.A., in **73,** 1123–1133 (1988)

223 Rhabdophane group: change the general formula to $XZO_4\cdot 1\text{–}2H_2O$

223 Rosasite group: change Petrovskite to Petrovskaite

223 Add: Roselite group

Monoclinic arsenates of general formula $Ca_2M^{+2}(AsO_4)_2\cdot 2H_2O$, M^{+2} = Co, Cu, Mg, Mn, Zn

Brandtite
Roselite
Wendwilsonite
Zincroselite

224 Scapolite group: delete Mizzonite from the list of minerals

224 Smectite group: change the general formula to $X_{0.3}Y_{2\text{-}3}Z_4O_{10}(OH)_2\cdot nH_2O$, change to Y = Al, Cr^{+3}, Cu^{+2}, Fe^{+2}, Fe^{+3}, Li, Mg, Ni, Zn; Z = Al, Si; in the list of minerals, delete Sobotkite, add Yakhontovite; at the end, insert compare Brammallite, Illite, Rectorite

225 Spinel group: add to the list of minerals, Zincochromite

225 Stannite group: change to A = Ag, Cd, Cu, Fe, Hg, Zn; add to the list of minerals, Velikite; change to Kesterite and Ferrokesterite are structurally related minerals

226 Add: Tapiolite group

Tetragonal oxides of general formula $A^{+2}B_2^{+5}O_6$, A^{+2} = Fe, Mg, Mn, Zn; B^{+5} = Nb, Sb, Ta

Byströmite
Ordonezite
Tapiolite
Tripuhyite

226 Add: Tetradymite group

Trigonal selenides, tellurides, and sulfides of general formula AX_3, A = Bi, Sb; X = Se, Te, S

Kawazulite
Paraguanajuatite
Skippenite
Tellurantimony
Tetradymite

226 Tetrahedrite group: add to the list of minerals, Argentotennantite

227 Zeolite group: third line, change to less commonly they contain Ba, Be, Li (?), K, Mg, and Sr

Appendix First page—Ankerite, change to calcium (magnesium, iron) carbonate

Appendix Second page—Benstonite, change to barium calcium magnesium carbonate

Appendix Second page—Bloedite, change to Blödite

Appendix Fourth page—Gadolinite, change to yttrium iron beryllium silicate

Appendix Fourth page—Huebnerite, change to Hübnerite, manganese tungstate

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NOTE: *The Glossary of Mineral Species,* fifth edition (1987) is still in print, and is available for $15 postpaid. A booklet-size reprint of the above additions and corrections, sized to fit within the *Glossary* in a map-pocket, is available for $2 postpaid. Order from the Circulation Manager, Mineralogical Record, P.O. Box 35565, Tucson, AZ 85740.

Notes from

Europe

LIEGE SHOW 1988

Let the moral of the story precede the story: *never try to cross international borders without a passport*. It was like this. Not having especially wanted to drive the 200 km's of dark autumnal back roads through the Ardennes Forest to get to Liege, I'd planned a prosaic train trip that would grind on through the night: Kaiserslautern to Mannheim, change for a long wee-hours ride up to Köln (Cologne), change again there and cross the Belgian border at dawn, reach Liege at 7:00 a.m. and have seventeen cups of coffee in the train station, hit the show downtown as it opened; simple. But halfway to Mannheim, in my crowded compartment, I realized that, not having reckoned this trip, somehow, as a case of "international" travel, I'd quite forgotten to bring that passport. So all the way to Köln, sleeplessly, I kept chastising myself (while plotting my strategy) for this remarkable thoughtlessness. At the border, when the two German customs officials came to my compartment to ask for my *Pass*, I mobilized, as planned, a crafty mix of genuine pathos and feigned *Dummheit*: pretended to think that my U.S.-Army-issued I.D. card would be sufficient; had then to explain that, no, I had no military travel orders because I was a civilian; had next to explain how a U.S. civilian comes to have a military I.D. card (too much to try to tell *you*); had to make clear what, exactly, my business in Belgium was, taxing my German to its heroic limits to make a mineral show sound plausible to them; invited them to search my handcarry bag to find *no* (whatsoever!) illicit drugs, photocopied spy secrets, or hand-held anti-tank weapons; pleaded at last (full pathos now kicking in) that really I had no way of getting home inside 24 hours, make that 48, should they actually throw me off the train at this desolate station and desolate hour. Finally, with relief, and with amazing grace, I took my tongue-lashing and submitted to what was probably the standard customs-cop lecture on the important theme *never try to cross international borders without a passport;* thus on into Belgium we—the train and I—skulked. And on the way home twelve hours later, as the inexpressibly slow local bumped, rolled and crept through the dark border lands, I panicked with every slight deceleration, fearing the outcome should I have to explain, in my Frenchlessness, all the same stuff to the Belgian guards; but when I spied the approaching Aachen (Germany) station I noticed that I had never felt so good about being let into this country from anywhere *without* a customs check.

Liege itself, as the friendly cabbie drove me into it through a fine morning rain, was a pleasure to see: a dignified, gray, grungy-genteel, distinctly Gallic place of wide traffic circles, pompous stone monuments, a bristling Gothic cathedral, a bright pedestrian mall, and little low footbridges over the Meuse River. The mineral show, nineteenth of its kind for Liege but a first for me, was held in an elementary school, the *Lycée de Waha,* whose gray facade, indignantly sandwiched between two modern commercial buildings, maintained snooty airs with its lintel of inspirational gilded Latin and Corinthian scrollings. The main show area filled only one modest squarish room just inside the door, and at first, disappointed, I thought that was all there was to it. But soon I discovered, in addition to an encircling upper level, a narrow corridor leading off into the dim educational bowels of the place—this corridor so densely lined on both sides with dealers' stands that threading down it in the inadequate light, amid the crush of showgoers, without knocking anything over, was plenty tricky. A wonderful corridor: high-ceilinged, plaster walls peeling; overtones or undertones (not quite smells) of mold and must and chalkdust. Behind another door, an incredibly smoky snack area with stand-up bar looked like a set from your favorite old French Resistance movie except that, like all the rest of the show, the room was full of chattering middleclass rockhounds, earnestly huddling professionals, and excited schoolboys—a clique of the latter busily shoving meter-long lumps of fossiliferous rock around on the long, brown, warped eating tables. This show on the whole, I'd say, was busier, happier, dingier and more vivacious than even an average French show, although the prevailing language was the same.

Little Belgium is hardly known for mineral treasures, but those modest occurrences that it does have were of course being featured by many local collector/dealers. Mostly the material consisted of rare minerals and/or microminerals from the Ardennes, but easily the nicest hand specimens were of pale yellow to medium orange twinned scalenohedrons of "dogtooth" calcite (resembling old Tri-State pieces) from Rhisnes, near Namur. There were some cabinet groups up to 20 cm across but dulled by limonite coatings; a few small groups showed nice orange translucency.

In keeping with the heterogeneous, mildly eccentric atmosphere of the show, there were many surprises, rarities and oddities (often quite inexpensive) from everywhere scattered about. For example, I saw a xenotime from Norway with an old A. E. Foote label; a wonderfully handsome 10 x 10-cm group of muscovite books standing up on matrix, from Middletown, Connecticut; a good miniature of danburite from Danbury, Connecticut; presentable small cabinet specimens of millerite and sal ammoniac from Kladno, Bohemia, Czechoslovakia; a group of magnesite rhombs to 1 cm on edge from Podredany, Czechoslovakia; and for a very low price I managed to add to my own collection a very sharp Madagascar euxenite floater single 2.7 cm long.

A fair number of dealers offered selections of newer things that I have reported on before in this space, so it seems a good time for an update or two. There were a few of the new pyromorphites from Villaviciosa de Cordoba, Spain, with which I've been madly in love for a year or so now; these were still vividly colored but all were small, and rather stiffly priced. One dealer had a few bright, Trepča-like galena and sphalerite specimens from the 9th of September mine, Madan, Bulgaria—the crystals usually too small for their wide, flat matrixes. More interestingly, one dealer had cleavages of cloudy yellowish gray and translucent diaspore 3 to 7 cm long, with small gemmy areas, from "Kütahya," Turkey. These were being hyped on their labels (with exclamation points) as "crystals" and sold at high prices, but I saw no true crystal faces. They did *not* really look like the cleavages and occasional gemmy terminated crystals of Turkish diaspore on which I reported from Munich two years ago, and, sure enough, my atlas shows Kütahya as lying well to the northeast of the Mugla-Aydin area given as the source of the earlier and better pieces.

Further, I saw at Liege the best Norwegian anatase on quartz I've seen in quite a while, and have been told that the famous Matskorhae locality (see vol. 8, no. 4, July-August 1977) is *not* dead after all, these being quite recently collected pieces. Quartz clusters to 10 cm wide studded with lustrous, blue-black, 1-cm anatase bipyramids, and also some loose anatase crystals to 3.5 cm long, were offered. Most of the crystals on quartz were damaged, as usual, but one dazzling miniature (for only about $100) and a thumbnail (about $60) were clean and unbruised and had anatase crystals covering 75% of the quartz surfaces.

At several stands were some quite honest-looking chalcanthite specimens from Broken Hill, New South Wales, Australia, showing straight-up spiky clumps of bright blue skeletal crystals on a rusty carbonate matrix; miniatures and small cabinet pieces were inexpensive, though not really first-rate display specimens. A similar comment can be made for the many offerings of Zaire uranium secondaries—one naturally looks for these in Belgium, what with the former Congo connection—showing mostly massive seams and sometimes microcrystallized vugs of minerals such as kasolite, curite, cuprosklodowskite and becquerelite in limonitic or black uraninite matrixes. I suppose that these rare minerals do have a special red-hot charisma to them, especially for micromounters, but I confess myself disappointed to have spotted no really striking larger specimens of any of them.

The Belgian dealer Willy Israel (Geraardsbergse Steenweg 13, B-9230 Melle) had a *large* (largest and best I've seen for some time) array of Tsumeb and other Namibian and South African material, including Tsumeb rarities like arsentsumebite, ludlockite, leiteite, nice arborescent groups of Tsumeb native copper, cobaltian smithsonite in sharp bright pink groups, good azurite and tennantite, etc. The most remarkable thing here, however, was a little collection of about ten thumbnails and small miniatures of the new very pale yellow-green thaumasite crystal groups from the Black Rock district, Hotazel, South Africa. Collectors have until very recently thought of thaumasite only as uninteresting chalk-white masses or annoying alteration coatings associated with crystallized zeolites, but these new ones—as heralded by the appearance of a few, less impressive, small thumbnails at Ste.-Marie last summer—are beautifully sharp hexagonal prisms to 1 cm across the basal pinacoid, in pleasing sparkly groups. The best one was a thumbnail for about $40 (no, stupidly, I did *not* buy it myself). According to Israel, the thaumasites came from one pocket worked by one miner in the summer of 1987, and were marketed (somehow) through his mother-in-law.

Another Belgian, Marie-Anne Castiaux of Brussels (sorry, I only got the telephone number: 02/466-09-20) had some excellent material from some well-known Peruvian localities, especially from the Alimon mine, Huaron, since 1985 the source of almost textbook-perfect chalcopyrite, sphalerite, rhodochrosite and other attractive crystals nestled singly on and in groups of needle quartz prisms. Good to excellent thumbnails, especially of chalcopyrite of this style, were going for only $6 to $12 here, though a few other Alimon mine specimens showing delicate Japan-law twins of quartz hiding among the needle crystals were far more expensive. Ms. Castiaux also had a couple of very good small wire silvers from a locality known mostly for its pyrargyrite: the San Genaro mine, Huancavelica, Peru. From nearby Bolivia came some gorgeous vivianite miniatures, and, the star of this show, a 3 x 5-cm ludlamite from Huanuni, with richly colored green sheaves on an oxide matrix for about $700. Finally—the unexpected again—there were some very nice small white dolomite matrixes with microcrystals and small macrocrystals of pale yellow sphalerite, from the classic locality at Lockport, New York.

Olivier Szentessy (B.P. 105 Petit, Lancy 1, 1213 Geneva, Switzerland) was very busy this past October in the Alps above Bourg d'Oisans, Isére, France, a place famous, of course, for some of the world's best gemmy brown axinite (now known as the species ferroaxinite). In this neighborhood Szentessy dug out a one-meter pocket that proved to be full of fine epidote of the Alpine type, i.e., in association with fibrous actinolite (*byssolite*) and snow-white adularia on a chlorite schist, like the legendary Untersulzbachtal, Austria specimens. The best of the epidote single crystals found was a 5-cm well-terminated prism, the best group a lovely 8 x 8-cm piece with abundant byssolite. The crystals, in both parallel groups and jackstraw clusters, have very high luster, and their prices, naturally enough, are high as well. Szentessy expects to keep prospecting in this region; he's hit no fresh axinite yet but is optimistic for next season since an unseasonable snowstorm cut off digging prematurely this year. Oh yes, he also had some purplish blue clusters of cubic fluorite, quite handsome when backlit, that he's recently collected at Fontsant, Var, France.

Although as I write this it's too soon for me to be very sure about this year's plans, my pleasant experience at the Liege show now inclines me to visit the one in Antwerp in April—for Antwerp itself is a fascinating old port city, and who anyway could resist words like "gratis toegang," i.e., "free admission," on the flyer? And certainly I'll try to see that my Toegang into Belgium *next* time is smoothed by a passport.

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Letters

TYPE SPECIMENS

Regarding the guest editorial by Dunn and Mandarino in the July-August issue ("The preservation of type mineral specimens"), we would like to offer our comments.

We agree that type material is extremely valuable to science and that sufficient amounts should be preserved in research-oriented institutions for future research, and to serve as permanent standards for the species. However, where there is an abundance of type material for a particular species, we think private collectors could (and should) be allowed a small amount without harm to the science. There are certainly some private collections which are more "professionally" curated than some public collections, and where type material would be safer. Many non-professionals are qualified to handle and own type material, and some public institution curators are not the best caretakers. Cases should be decided individually by the scientists involved, using common sense. To declare all scientists superior in trustworthiness to all non-scientists is pompous and inaccurate.

If a scientist chooses to release a portion of the type material to a responsible dealer or collector who then distributes that material (unmodified in any way) to public institutions, those type specimens should not be considered as having lost their "pedigree." The mere touch of non-scientists should not condemn type specimens or any other "studied" material to the waste-heap, as if we all had some dangerous character flaw to which professionals are immune.

Particularly offensive was a statement not in the guest editorial itself, but in the following "Formal definitions of type mineral specimens" by the same authors: "To maintain the guarantee of authenticity, type specimens should never be *handled* or owned by non-scientists" (italics ours). This would mean that an interested amateur could not visit a museum and be permitted to study (and handle) any type specimen! What an insult to the serious amateur mineralogist. Almost without question, it was an amateur who started out with the specimen by collecting it in the field. Now that a scientist has proven something of consequence on it, it must never again be touched by mere mortals? Again, the authors have carried their argument too far.

Drs. Dunn and Mandarino write as representatives of the Smithsonian Institution and the Royal Ontario Museum. We'd like to know if those institutions actually adhere to a policy of considering type material "handled or owned by non-scientists" to have lost its pedigree. If a private collector or dealer provides type material, is it written off as "tainted"? Further, it has been our understanding that for years the Smithsonian has had a fine staff of "non-professional" volunteers who have done countless hours of outstanding work for the mineral department. Have the type and studied materials handled and catalogued by these non-scientists lost their value?

Finally, we would like to say that the continual barrage of guest editorials in the *Mineralogical Record* by Dr. Dunn and his colleagues criticizing practices of the non-professional community are very discouraging to the hobby. Whether we agree with them or not, individually, the cumulative effect is to demoralize collectors and turn them off to the scientific establishment and to collecting. As the authors have said, "there are millions of specimens out there"; and practically all of them have been salvaged by non-scientists, a service for which science owes a great debt. Surely, the non-professionals deserve more encouragement and more gratitude in the balance, rather than only criticism, belittlement, prejudice and stifling restrictions.

Forrest and Barbara Cureton
Cureton Mineral Company
Tucson, Arizona

Response to Forrest and Barbara Cureton:

Many of the issues raised by the Curetons are irrelevant and not worthy of attention. Some of those we ignore; they are wholly non-germane to our editorial, and should be addressed to others.

To the extent, however, that their statements imply a response to something we did not state, they should be addressed in order to clear the air, so-to-speak. For example, we did not "declare all scientists superior in trustworthiness to all non-scientists"; therefore, the Curetons' statement of this being "pompous and inaccurate" is a "red-herring," useful only in diverting attention from the issues at hand. In a similar vein, their statement that "the mere touch of non-scientists should not condemn type specimens . . . to the trash heap" is another non-germane, emotion-laden irrelevancy. Their statement that "almost without question, it was an amateur who started out with the specimen" is in great part inaccurate and unsupported by evidence; a great many type mineral specimens have had no prior connection with amateur collectors. The sarcastic assertion, unsaid by us, "Now that a scientist has proven something of consequence on it, it must never again be touched by mere mortals," is unworthy of response. So much for nonsense.

Turning to the substantive part of the Curetons' letter, we find a few arguments that are worthy of some brief response. These are in their statements:

(1) "Where there is an abundance of type material for a particular species, we think private collectors could (and should) be allowed a small amount without harm to the science."

(2) "If a scientist chooses to release a portion of the type material to a responsible dealer or collector who then distributes that material (unmodified in any way) to public institutions, those type specimens should not be considered as having lost their 'pedigree.' "

Turning to the first of these points, it is useful to recall that most type specimens are very small, no larger than hand-specimens, and exceedingly few exist which would permit such a distribution. If indeed such material existed, then the type material is only that part formally deposited in a public institution. We understand that such distributions have been made in the past, and we consider the distributed part as tainted and not type material. The rest of the Curetons' statement implies that they consider themselves suitable judges of what might harm science; we don't agree. We think such judgments about this very miniscule but extremely critical part of the world's specimen material should be made by those operating free of a profit motive, subject to institutional controls, and whose **primary responsibilities** are to the benefit of science. Private mineral dealers are not qualified for this task.

Turning to the second of these points, we do not agree. Plainly spoken, our position is as given in our editorial and we are unpersuaded to modify it. One reason is that there is no way that one can be sure that the material is "unmodified in any way," as the Curetons put it. A more important point, however, is the matter of the scientists's responsibility. While we are well aware that there are many responsible collectors and dealers, and do not impugn their reputation, our concerns lie elsewhere: with the responsible scientist. Rehashing specific examples and arguments of yesteryear might be useful to historians; we leave it to those trained in such matters. Our concerns are with the present and the future, and the integrity of the type specimen base. We have taken these actions, and written these papers, to influence what will be the standard of ethical professional behavior. It is our position that responsible scientists will wish to cooperate and do what is best for science. If they do, then the whole scenario put forward by the Curetons is redundant. That is our intent, and our great hope.

Lastly, the Curetons address a "continual barrage" of guest editorials by one of the writers (PJD) and his colleagues, which, it is stated, are "discouraging to the hobby," and "demoralize collectors and turn them off to [sic] the scientific establishment and to collecting." Wow!! Such power!! Dunn never knew he had such abilities!

Seriously, these assertions are nonsense. In addition, we do not accept that the Curetons speak for all collectors. Three editorials by Dunn and others (on fakery, fragmentation, and types; not barrages) indeed have been critical of **some** harmful actions of **some** in the commercial community. This is as it should be; this is as it will be. Although much of the mineralculture and mineral-publishing community is addicted to a policy of pandering to moneyed interests, we have no apologies to make for criticizing practices harmful to science and we will continue to do so. The easiest way to avoid such criticism is to behave in a more responsible manner. The criticized editorials have addressed these subjects in both a critical and a constructive manner and should be re-read (*Mineralogical Record,* **17**, 226; **19**, 226–227).

The Curetons close by stating that "nonprofessionals deserve more gratitude and encouragement in the balance, rather than only criticism, belittlement, prejudice and stifling restrictions." We agree; we each have conducted our professional practice in such a manner, and we stand on our well-established records of contributions to the collector community.

Dr. Pete J. Dunn
Smithsonian Institution
Dr. Joseph A. Mandarino
Royal Ontario Museum

I read with interest the recent editorial by Drs. Dunn and Mandarino concerning the preservation of type mineral specimens. There are two important issues raised by this editorial. The first concerns the fate of type mineral specimens. The second has nothing to do with type minerals, but concerns the tone of the editorial itself.

Regarding the first issue, I agree with the authors with respect to the seminal importance of type specimens and the necessity that type material be stored in appropriately curated institutions. We disagree on the amount of material that needs to be deposited. Common sense should govern decisions, depending in each case on the quantity of type material extant. Absolute rules such as proposed in this editorial are usually unenforceable. In fact, I fear that the policy espoused by the authors might actually *decrease* the amount of type material deposited in their institutions. Do they intend to refuse to accept type material if the owner insists on retaining some to distribute as he or she sees fit? Will they reject donations of type material already in private hands? On the other hand, why would private individuals want to place in the authors' museums any type material they currently may hold if such material is "tainted" and of impaired scientific value?

However, the authors are entitled to present their opinions, which raises the more troublesome issue. It is important to recognize that the editorial is indeed the *personal* opinion of the authors, despite the fact that, by virtue of their positions, they appear to be *de facto* representatives of their respective institutions. The authors should make clear to the readers of the *Mineralogical Record* that their thoughts do *not* reflect official policy at their institutions.

I am particularly concerned that, in stating these personal opinions, the authors have used language which implies an attitude of condescension in regard to the level of scientific sophistication of the readers of the *Mineralogical Record* and the general population of mineral collectors. Drs. Dunn and Mandarino make a curious distinction between collectors and scientists, and appear very concerned about an assault by destructive forces on "our science." Who does "our" include (and exclude)? Can collectors not be scientists? Is there no scientific merit in the accumulation and study of minerals by private individuals? Some of us have important suites of various categories of minerals or localities, from which specimens are frequently borrowed by investigators. Many of these collections will ultimately reside in museums. I have a great deal of respect for these authors, who have made significant contributions to mineralogy; but by whose authority are they empowered to define "science" and who may practice it? Among the ranks of mineral collectors are serious amateur mineralogists who have substantial training in both mineralogy and other scientific disciplines, and are established scientists in their own right.

I find particularly objectionable the use of pejorative words such as "tainted." This kind of inflammatory language does little to advance the authors' purpose, which I assume is to convince the readership of the validity of their viewpoint. I would have enjoyed hearing the response of men such as the Canfields or Roebling to the editorial. Large public collections cannot survive without the good will and support of concerned private citizens. It would seem to me more politically astute for the authors to encourage our support in a positive manner rather than to make sweeping negative generalizations and hurl gratuitous insults.

Mark Feinglos, M.D., C.M.
Associate Professor of Medicine
Duke University Medical Center
Durham, North Carolina

Response to Mark N. Feinglos

Some of the points raised by Dr. Feinglos are interesting, peripheral, and stimulating; they pose topics for future discussion. These, however, together with some of the rhetoric, are wholly non-germane to our editorial on type specimens and should be addressed to others. We will stick to the subject at hand.

To the extent, however, that irrelevant comments cloud the air, they should be briefly addressed. Dr. Feinglos asks: "Can collectors not be scientists?" Surely some are, and vice versa, but that is not at issue here; not at all. His question would have been better framed as "Can collectors not be curators of type specimens." To that, we say no. The motives of those who seek to privately own type specimens, and of those who are entrusted with preserving them for posterity, are irreconcilable. What is needed is a policy of keeping these few critical specimens in public, institutionally appointed hands. Our editorial needs a more careful reading by Dr. Feinglos; it presents our position clearly and will not be repeated here.

On some germane points, response by us is appropriate. Dr. Feinglos's assertion, in connection with the amount of type material to be preserved in public institutions, that "common sense should govern decisions," is unsupported. Indeed, the track record of the last 20 years' worth of "common sense" is not good. That is also why we wrote our editorial, which is, by definition, our personal opinion. Although a new mineral may be found in large quantities, that is an exceedingly rare happenstance. In most cases there is but one hand-specimen or smaller. Yes, we are stating that **all** the **studied** material should all be preserved in public institutions. Nothing is to be gained by private ownership; nothing at all! As we stated previously, we are not asking for much, only a very few of the many, many millions of specimens out there. The lack of clamor over our editorial suggests that most collectors see this as a reasonable request. We thank them for this implicit support, and that which we have received directly, and we regret that Dr. Feinglos does not agree.

Although Dr. Feinglos takes issue with our use of the word "tainted," he does not offer a better substitute word for these "purported type" specimens which, even if they were once legitimate, are of no use now to the science as type specimens, having lost their pedigree by private ownership. We cannot think of a better, socially acceptable, word to describe such specimens. We thus choose to retain the usage of "tainted" in the sense in which we used it in our editorial, and encourage the reader to review it.

Dr. Feinglos also takes issue with our use of the words "scientist" and "collector." Contrary to his assertion, we took pains not to define these terms; thus his argument on those grounds is baseless, and non-germane. Our usage of the word "collector" is correct and intentional: the principals involved in the well-focused subject of our editorial **are** scientists **or** collectors; the words are appropriate and could not be more so. The *Mineralogical Record* is first and foremost a collector's journal. Our words were chosen to communicate with collectors; if Dr. Feinglos wishes to see them in another light, he may do so, but we are unconcerned. Partly as a result of our conversations with many collectors, we doubt that Dr. Feinglos speaks for "collectors" in general. Some words of Shakespeare, to wit, "Much ado about nothing," address the fourth and fifth paragraphs of Dr. Feinglos's semantic complaint.

Dr. Pete J. Dunn
Smithsonian Institution

Dr. Joseph A. Mandarino
Royal Ontario Museum

(continued from page 288)

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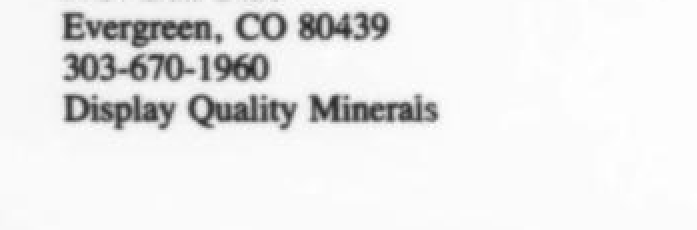

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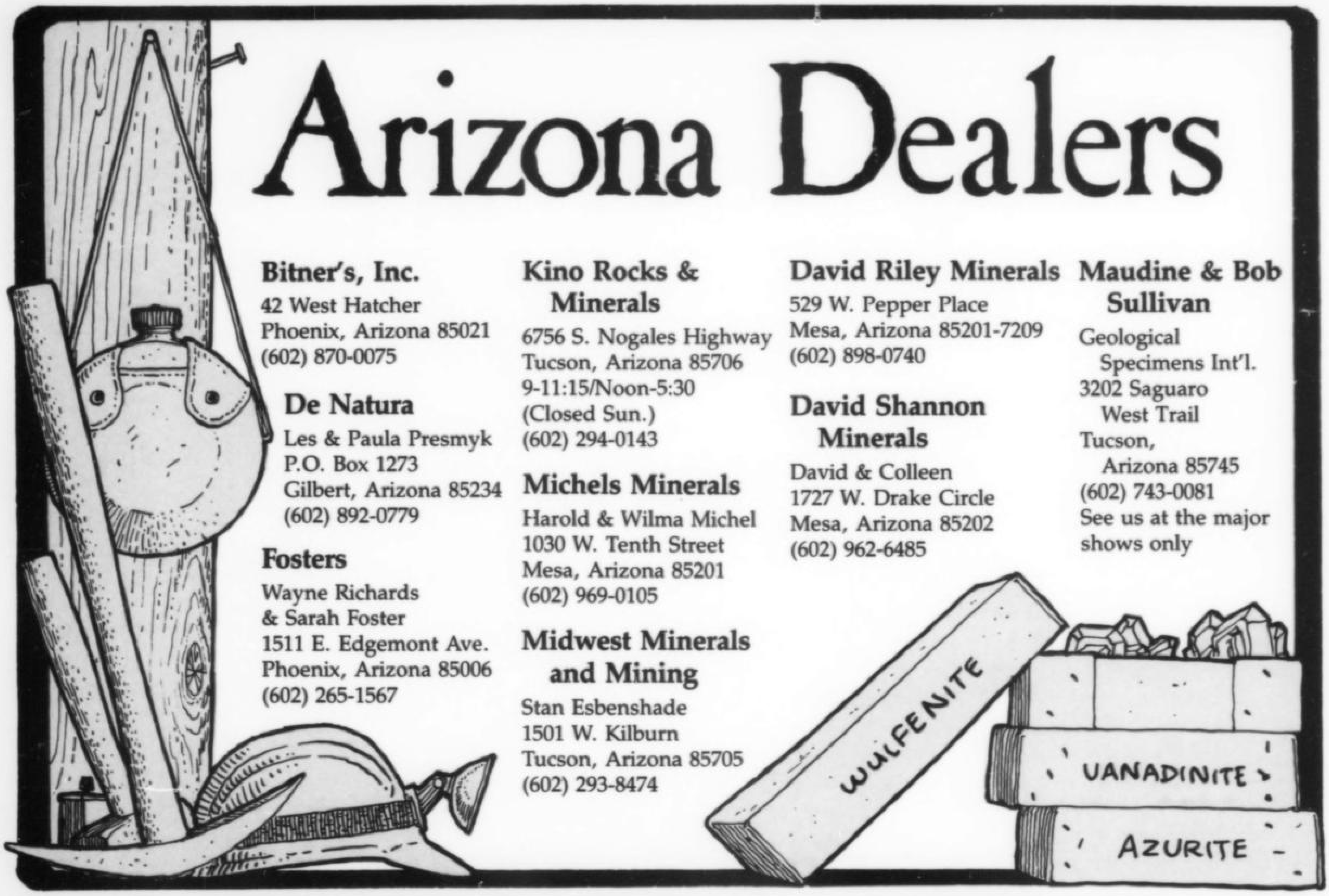

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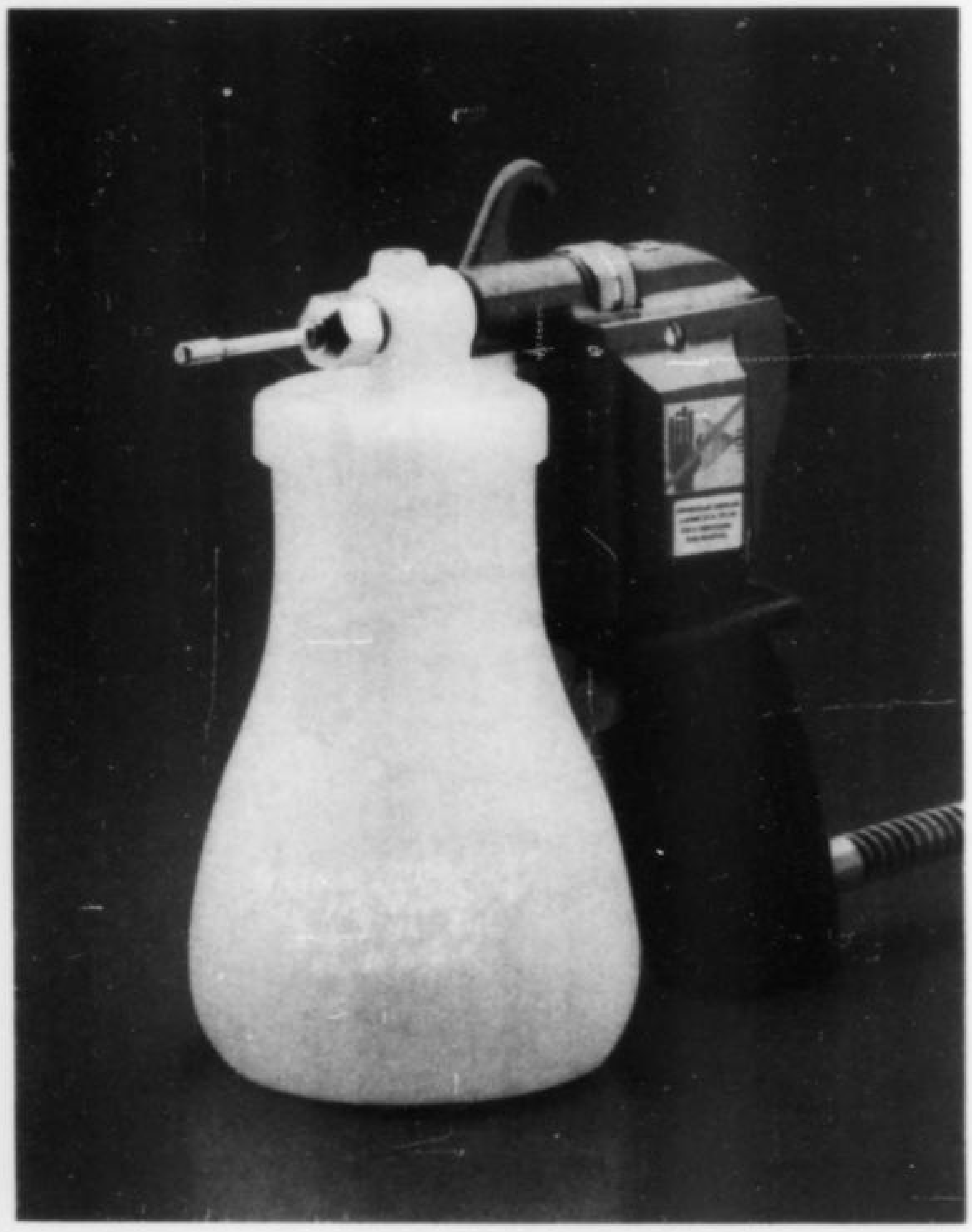

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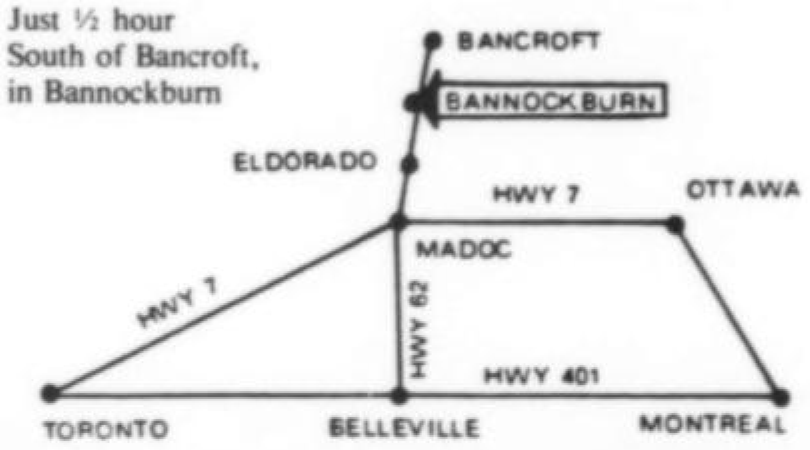

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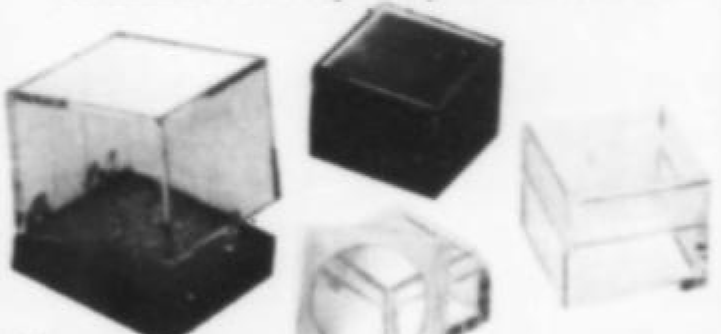

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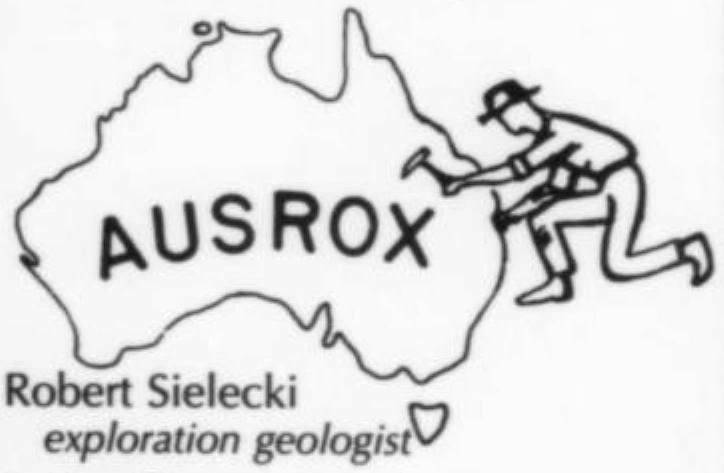
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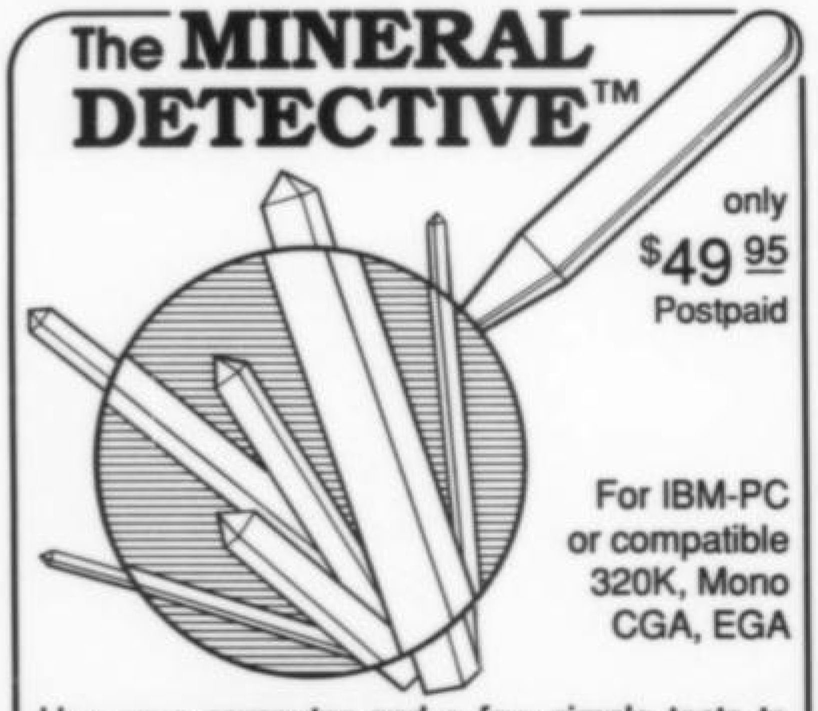

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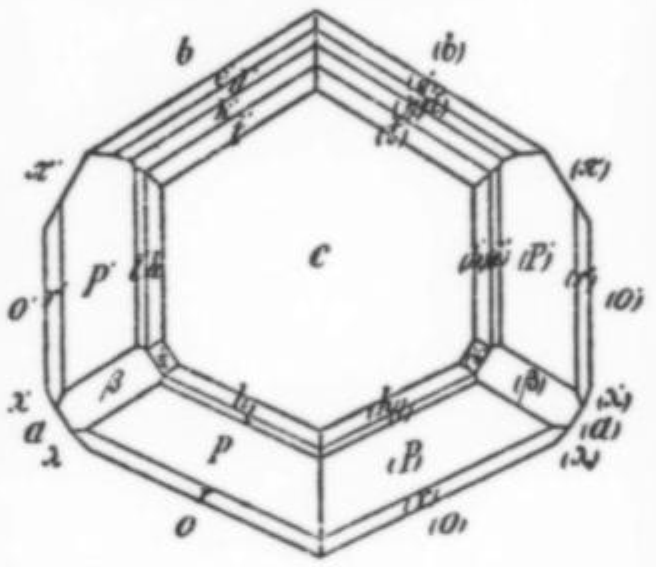

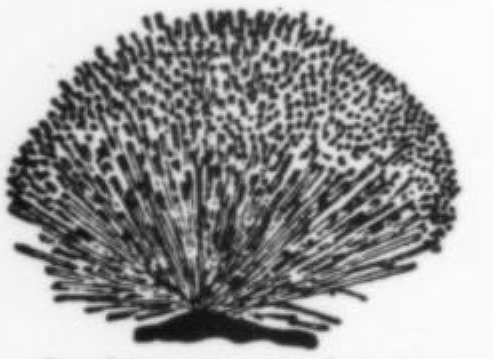

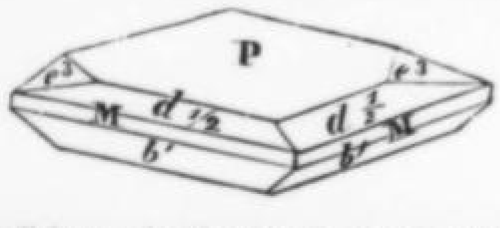

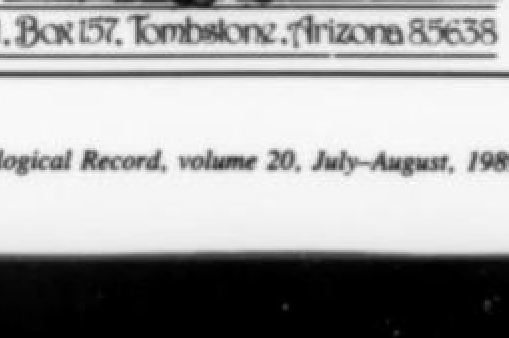
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All advertising in the Mineralogical Record must be paid in advance of the closing date. Telephone orders not accepted. Write to the editor for rates.

Closing dates:

Jan.-Feb. issue	Oct. 15
March-April issue	Dec. 15
May-June issue	Feb. 15
July-Aug. issue	April 15
Sept.-Oct. issue	June 15
Nov.-Dec. issue	Aug. 15

An additional 20 days past the closing date are allowed in which advertisers may make changes (excluding size changes) in ads already paid for.

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Tucson, AZ 85740
602-297-6709

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Tucson, AZ 85715
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