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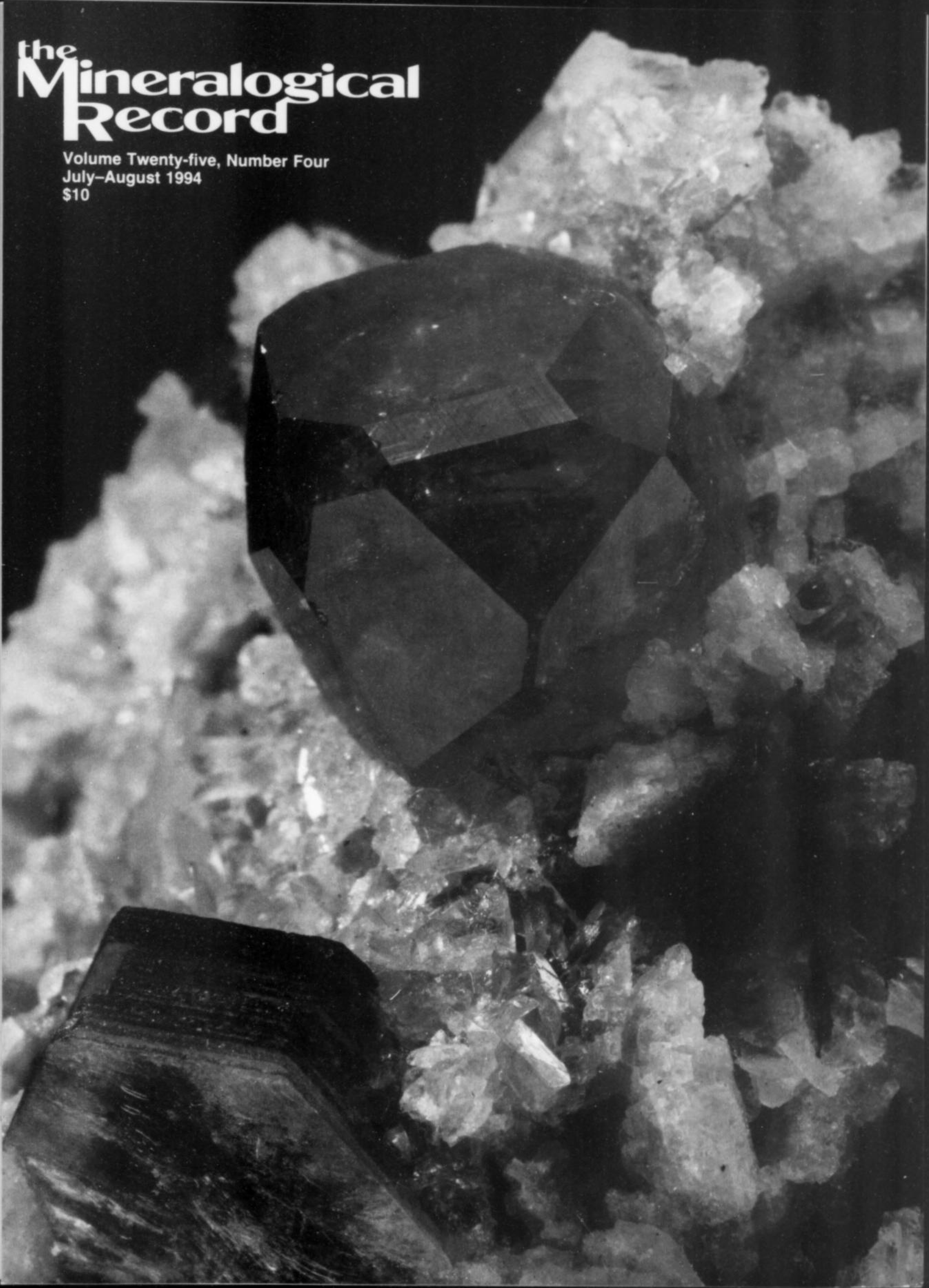


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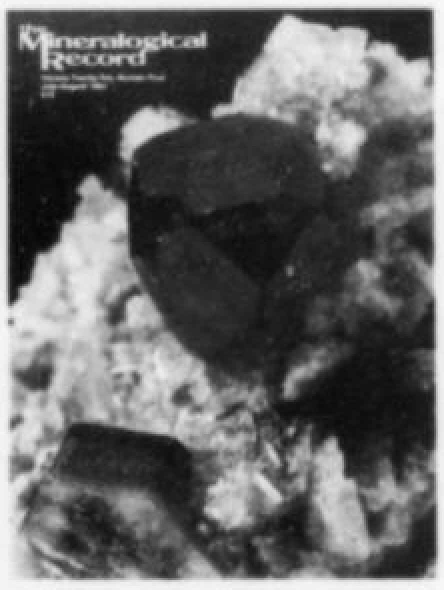
Articles

Columns



COVER: SPESSARTINE crystal (1.2 cm) on lepidolite and euclase, from Rio Grande do Norte, Brazil. Michael Scott collection; photo by Harold and Erica Van Pelt.

notes from the EDITOR

SPECIMEN BASES FOR DISPLAY

Many years ago I wrote a short article on some of the methods that can be used to mount specimens in a fixed position for display (vol. 8, p. 400–402). Wax, oil-based clay, plaster, wood, and styrofoam were among the materials discussed for use as specimen bases. My favorite technique at that time involved the use of Play-doh, a water-based clay that can be fashioned into specimen bases, removed and allowed to dry hard, then sanded, painted and glued back on the specimens. I like this method because the base is inconspicuous or invisible from the front, unlike plastic or wooden mounting blocks, and Play-doh will not stain matrix or cloth case liners.

The only problems with Play-doh are that it shrinks when drying, and that it can be somewhat hydrophilic, that is, it can absorb moisture out of humid air and become soft. A coating of gesso is needed to seal the surface in wet climates. Furthermore, unless the base is painted with sealer, the specimen cannot be washed in water without damaging the base.

Since that time I have become aware of a product that can be used in the same way but lacks those disadvantages. It is a type of modeling clay made by the German art-supply company Eberhard Faber Gmbh (D-8430 Neumarkt), called *FIMO* clay. It comes packaged in 5 x 5-cm blocks that are available in a range of colors including white, black, limonitic browns and tan. Each block costs about $2.

The clay is a bit stiff until it has been thoroughly warmed and worked by the hands, but it can be modeled with a pleasantly smooth surface, and will remain soft relatively indefinitely. Heating* the finished base in an oven at 265° F for 30 minutes or so causes the clay to permanently harden, without the slightest bit of shrinkage or sagging. It can then be glued onto the specimen.

I realize that most collectors would prefer their specimens to sit naturally in the best orientation, without propping up or mounting. Although some judicious carving and shaping of specimens can help to achieve this in some cases, many specimens still need help or stabilization if they are to be safely exhibited in their most aesthetic pose. FIMO clay is the most elegant solution I've seen to this problem.

PROGRESS REPORTS

Glossary of Mineral Species 1995

We have been sold out of the last (1991) edition of the *Glossary* for some months now, and authors Michael Fleischer and Joseph Mandarino are currently hard at work on the next edition. In response to many requests, they have agreed to include two major additions: (1) type localities for all species, and (2) formulas for all species in the group listings at the back, to facilitate comparisons between group members. These changes should make the new *Glossary* even more useful.

Production cost estimates are not yet available, since we don't yet know how many pages will be required to accommodate all the new information. But we plan to have the first copies available at the next Tucson Show in February.

25-Year Index

The 14-year index, produced for us some years ago by the Friends of Mineralogy, has been a significant aid to users of the *Mineralogical Record,* but is now rather long out of date. We have been working for several years on a *new,* cumulative 25-year index which will take its place. It is being compiled primarily by Ed Clopton and myself, and will include some useful new features, particularly a photo index and a title key-word index giving complete article citations. As everyone is now aware, the binding of the 14-year index was ill-chosen and tended to come apart with use. The 25-year index will be bound hardcover with a sewn (not glued) binding so that it will last under heavy use. This will probably be the last index to be cumulative back to volume one; the next one will cover only volumes 26–35. It is our plan to have it ready for sale within the first few months of next year.

IMA-APPROVED NEW SPECIES

As most readers know, the International Mineralogical Association (IMA) has a committee which passes judgment on descriptions and names of potential new mineral species prior to their publication (see Dunn and Mandarino's article on the workings of this commission in vol. 19, p. 319–323). Following approval by the commission, the authors and the mineral names they have proposed have priority over all others, provided the formal descriptions are published within two years (extensions are often given). The commission formerly considered all information on approved but unpublished species to be confidential and proprietary; only the authors of the descriptions were allowed, if they wished, to disclose any data prior to official publication.

However, the commission has reviewed this policy in recent years, and has decided that a distinct service to the mineralogical community could be rendered by allowing the publication of short descriptive summaries of newly approved species. The names of the authors submitting the proposals are not revealed, nor are the species *names* and *type localities*. The limited information provided nevertheless serves to inform other researchers whether potential new species they are investigating have already been discovered and described by someone else. This helps to prevent wasted duplicate effort. The information is also interesting to non-researchers and species collectors who enjoy following the unfolding knowledge of mineralogy as it is generated.

Dr. J. A. Mandarino, Chairman of the IMA Commission on New Minerals and Mineral Names, has recently forwarded to us the just-released list of approved species from 1992, and promises the 1993 list soon. It is reproduced in this issue (p. 316–317) for the interest of our readers.

MINERAL STORIES

We have currently exhausted our stock of mineral stories, with the publication of those on pages 307–309. Everybody has a good one they can tell; why not share it? Write up a rough draft and send it to Larry Conklin or the editor. Or just call us and tell us a story over the phone and we'll write it up for you.

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*Warning: overcooking can release harmful fumes.

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EARTHQUAKES AND MINERAL COLLECTIONS

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Natural History Museum of Los Angeles County
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Los Angeles, California 90007

Of all natural disasters, earthquakes may be the most terrifying because they usually occur without warning and have the potential for tremendous destruction. The science of seismology has come a long way in understanding earthquakes, estimating risk, and devising ways of lessening their destructive effects, but much remains to be accomplished. Both museums and private collectors face some very special problems in storing and displaying priceless artifacts in seismically active areas while protecting them from harm.

INTRODUCTION

Art and antiquity museums, often blessed with much greater funding than natural history museums (or private collectors, for that matter), have devoted considerable study to earthquake preparedness and have sometimes enacted elaborate measures to protect their objects. It is ironic that mineral curators and collectors, though usually well-versed in the basic mechanics of earthquakes, often fail to seriously address the danger to their specimens in storage and on display. During the last 23 years, three moderately strong earthquakes have occurred in the immediate Los Angeles area. A magnitude 6.5 quake in 1971 was centered in Sylmar, in the San Fernando Valley, about 23 miles northwest of the Natural History Museum of Los Angeles County in central Los Angeles. A magnitude 5.9 quake in 1987 was centered at Whittier Narrows about 12 miles west of the Museum. A magnitude 6.7 quake in January of 1994 was centered in Northridge, again in the San Fernando Valley, about 19 miles northwest of the Museum. These earthquakes have provided opportunities to appraise the danger to mineral specimens in storage and on display in institutional and private collections and to analyze the effectiveness of various storage and display techniques in preventing earthquake damage.

The most important of the many interrelated factors to be considered in assessing and minimizing risk are: (1) the statistical frequency and strength of earthquakes in the area, and the location and nature of known active faults; (2) the stability of the surrounding building; (3) the stability of the storage or display structure housing the specimens; (4) the method used to contain, mount, or support the specimens; (5) the orientation of specimens, particularly with respect to their mass and center of gravity; (6) the nature of the surface upon which falling specimens will impact, and the distance specimens are likely to fall before impacting it; and (7) the durability, hardness, and structural strength of the specimens themselves.

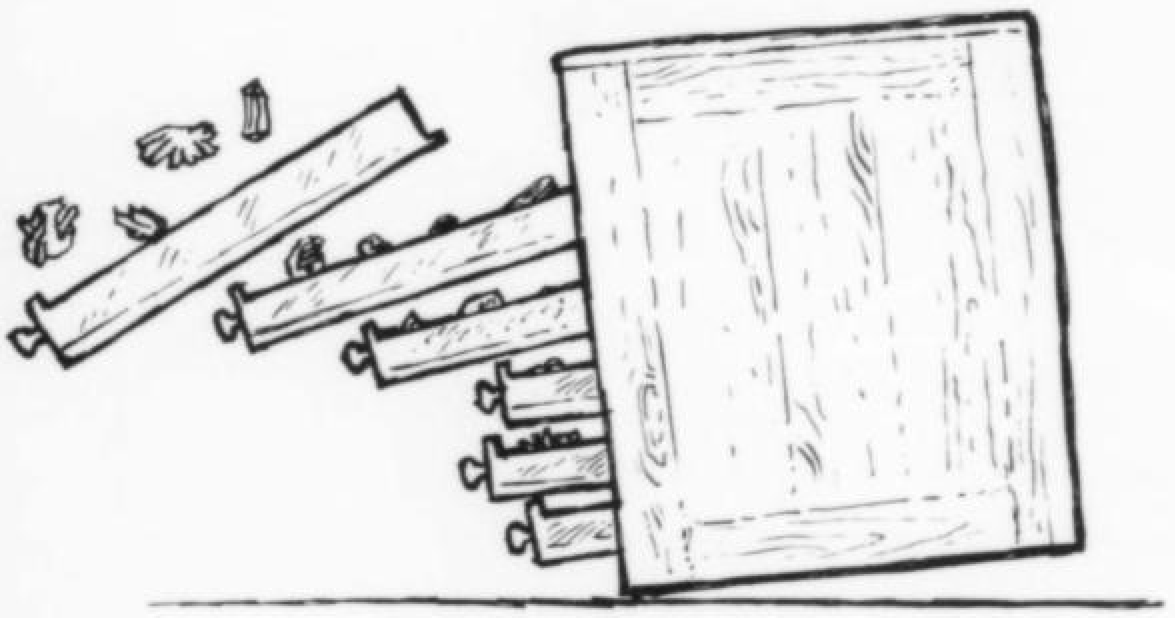
EARTHQUAKE STATISTICS

Most mineral and gem collections are not at significant risk simply because they are not located in earthquake-prone areas. The precautions taken should be predicated on the strength of earthquakes documented in the area. It is well-known that the force of an earthquake will diminish with distance, but in an area such as Los Angeles there are many active faults that are hidden beneath the surface and have never been mapped. The Richter magnitude 5.9 Whittier Narrows quake of 1987 and the magnitude 6.7 Northridge quake of 1994 both occurred on previously unknown faults. In addition, the quake and the motion it generates can be quite unpredictable. The Northridge quake produced a surprisingly irregular pattern of damage, apparently because earthquake waves interacted after bouncing off of surrounding geologic structures. The magnitude of an earthquake increases about 30-fold with each whole number increment on the Richter scale. The Sylmar, Whittier Narrows and Northridge quakes are therefore small compared to the "big one" of magnitude 8 which is considered possible in the Los Angeles area.

THE BUILDING

If the building housing the collection suffers great structural damage, any precautions taken specifically to protect specimens may have been in vain. Even if the specimens are not damaged, the danger to persons entering the structure may cause local officials to prohibit the removal of the specimens before demolishing the structure. A medical office building in West Los Angeles, though still standing, was condemned after the Northridge quake and no one was allowed inside to remove irreplaceable medical records, let alone other valuables. Unreinforced brick buildings are at greatest risk, but even those framed by iron girders will not fare well if they do not meet earthquake standards. Though costly, the retrofitting of older structures often proves effective and it is a small price to pay for the safety of both persons and specimens.

Another important factor to consider is the nature of the ground beneath the building. Recent sediments, clays or landfill may be thixotropic and consequently may "liquefy" during an earthquake, compromising even the best structures if their foundations do not attach to bedrock.

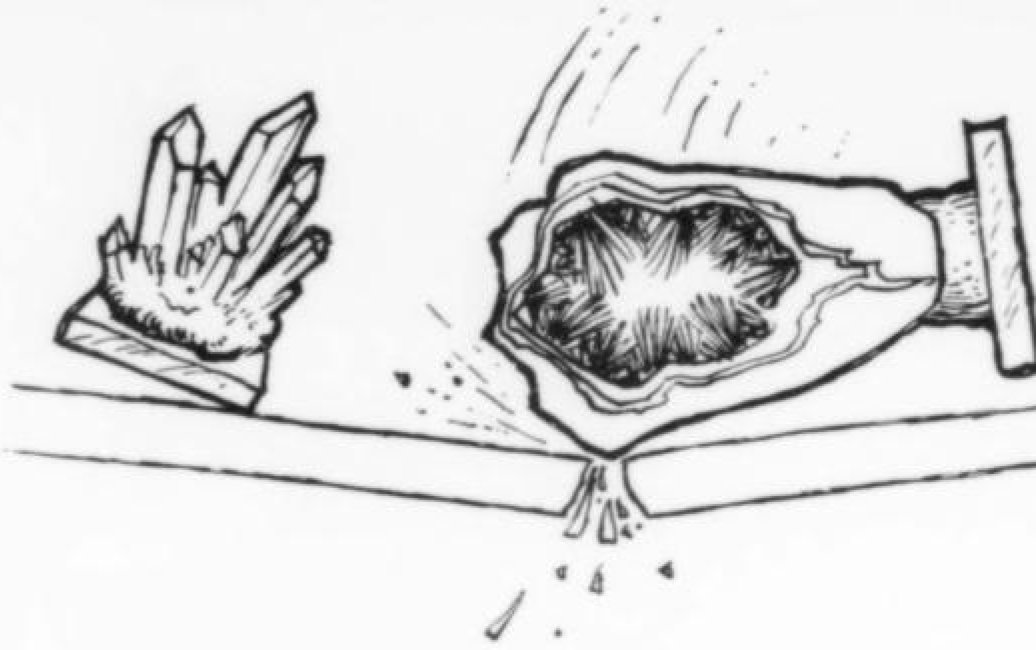


THE CONTAINING STRUCTURE

In considering the casework containing the specimens, the first consideration must be its resistance to falling over or collapsing. Cases consisting of drawers in an assembled frame, even if they are firmly anchored to walls, may fail because of the stresses of their heavy shifting load. Modular cases that are significantly taller than they are deep are at great risk. They must be securely fastened to the wall and/or floor. Surprisingly, the heavier the cabinet and its contents, the greater the risk. Remember that as the ground and building move, the inertia of the case will cause it to resist this motion. Heavy cases will exert a tremendous force on the fasteners holding them to the wall or floor. A seemingly impervious floor safe can be easily toppled by a quake if it is very tall, and its mass makes it particularly difficult to secure. Drawers within cabinets, particularly if they slide easily, should be completely immobilized when not in use. The force of a quake can be sufficient to defeat the stays designed to prevent drawers from sliding all the way out in normal use. The Northridge quake wreaked havoc at one local institution, where the collection drawers were thrown out of a tall framed structure, and a tall floor-safe toppled onto them.

When on display, specimens are exposed to greater danger since they generally cannot be confined to individual protective enclosures. Shelves, the most common components of display structures, are also potentially the most dangerous. A long, relatively thin glass shelf will flex during a quake, setting the specimens on its surface into even greater motion. If the structural components holding the shelf fail, or if the shelf itself breaks, it will pancake onto the shelves below, destroying all of the specimens in the case. In this way the entire private collection of Willard Perkins was destroyed in the Sylmar quake of 1971.

George Holloway of Stevenson Ranch, about 12 miles northwest of the epicenter of the Northridge earthquake, took many precautions in the display of his fine collection. All of his specimens were well-secured to display bases and in turn to the shelves beneath. The thick glass shelves were well supported in seemingly sturdy custom-made cabinets. Unfortunately, the tall cabinets themselves were not fastened to the walls. They toppled in the quake, partially collapsing in the process, and most of their contents were destroyed. George has since been advised that the cabinet structure itself was flawed, and even had the cabinets been securely attached to the walls, they might have collapsed leaving only the back panel standing.



The moral of these stories is that flaws in the containing structure are probably the most crucial in compromising the safety of an entire collection during an earthquake.

SUPPORTING SPECIMENS

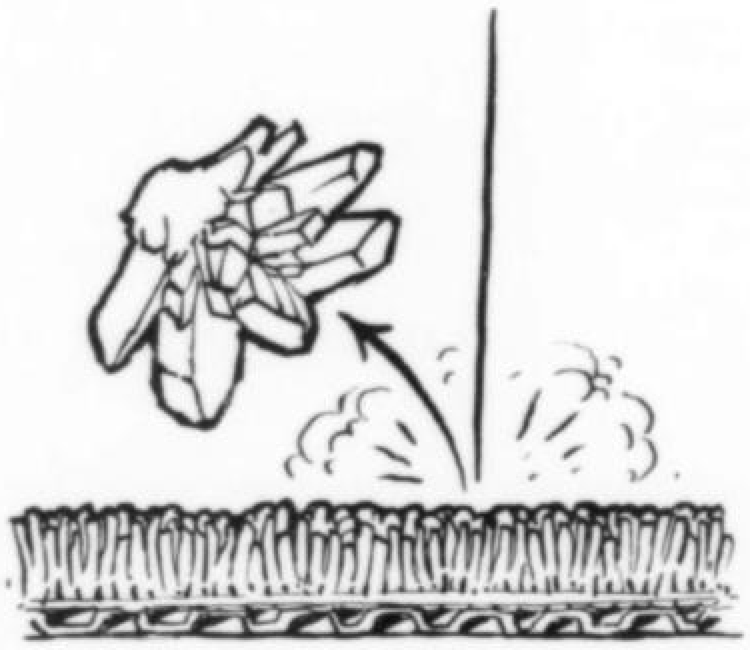
Specimens stored in drawers should be confined to high-walled individual boxes, preferably with some padding and supporting material so that they will not roll and come into contact with each other. These precautions are even more important for preventing damage resulting from the much more frequent and often equally abrupt force involved in simply opening the drawers. Some people have recommended additional padding on *top* of the specimens; however, while this will undoubtedly be useful in the event of an earthquake, it can cause damage to delicate specimens during normal access.

The methods used to mount and support specimens on display are crucial to their well-being. The specimens must be secured so that they will not fall over, damaging themselves and perhaps others nearby. Adhesives are commonly used to affix specimens to exhibit elements. Besides strength, the choice of adhesive should be based upon other considerations such as appearance, chemical reactivity with the specimen, and ease of later removal. We have employed both silicone and hot glue for securely mounting specimens; however, be aware that neither of these adhesives are recommended by conservators because of their chemical reactivity and tendency to outgas over extended periods. Many dealers and collectors use sticky, pliable compounds such as "Blue-tac" to attach specimens to bases. These materials are reasonably effective as temporary adhesives for smaller specimens, but will soften under hot lights; the same admonition regarding reactivity holds. Museum conservators often recommend archival-quality wax, sometimes referred to as museum wax. The holding power of wax is limited, however, and it must be applied with some force which may damage more fragile specimens. Contoured mounts made of materials such as plaster, plastic or wood can be employed for support of problem specimens. [See *Notes from the Editor* in this issue.] Posts, brackets, wires or monofilament line can also be used effectively. In some special cases, particularly for very tall specimens, the use of a combination of methods may be warranted.

An approach that has thus far proven highly effective in our displays involves gluing specimens to Plexiglas bases that are free to slide on very stable Plexiglas shelves. The ability of the bases to slide minimizes the stress on the adhesive attaching the specimen to the base, and the entire assembly is less likely to fall over. Of more than 600 specimens mounted in this way, only one fell over during the 6.7 Northridge quake. That specimen had not been attached properly to its base. There was less movement of the specimen bases in the earlier 5.9 Whittier Narrows quake, yet many more fell over because they had not been affixed adequately to their bases. The disadvantage of this method is that virtually all of the display cases had to be opened and the specimens repositioned following the Northridge quake, but at least the specimens were preserved, which is the primary goal.

SPECIMEN ORIENTATION

The Whittier Narrows quake of 1987 demonstrated to us that the specimens at greatest risk of falling over are those that are both tall and of large mass. Subsequently, any such specimens on display that could not be very firmly secured were either oriented horizontally or removed from display. For that reason and because of the more effective use of adhesives to secure specimens, the specimen damage suffered from the stronger Northridge quake of 1994 was negligible.



IMPACTING ON SURFACES

The most severe specimen damage usually results from impact on relatively hard surfaces when the specimen has fallen from some height. It naturally follows that situations which could result in this occurring should be avoided. It is advantageous for collection storage and handling areas to be carpeted; specimens which fall or are dropped to the floor will not suffer as greatly. Incorporating soft surfaces such as velvet inside display cases can also be effective, both as a design treatment and as protection against earthquake damage. Specimens should not be stored on open shelves without some barrier to prevent them from sliding off. It is not enough to have sturdy, stable shelves in exhibit cases and safes. There must not be sufficient space *surrounding* the shelf for specimens to fall off the edge. Allowing specimens to slide on their bases rather than topple does little good if they slide off the edge of the shelf. In our gem display the stones are placed in metal cradles that are set on a display surface without any attachment. Because the surface is velvet, because the gems have no distance to fall, and because the cases are firmly bolted to the floor, the chance of damage from earthquakes is judged to be negligible.

SPECIMEN DURABILITY

A final consideration is the durability of the specimens themselves. A jade boulder or meteorite might suffer little or no damage if the building around it collapsed, while a delicate crocoite could be destroyed if it rolled a few inches on a padded surface. With this in mind special care should be afforded to particular specimens and in the placement of specimens that might topple onto one another in the event of an earthquake.

CONCLUSION

These observations and recommendations address only moderately strong earthquakes. An earthquake of magnitude 8 or greater centered in close proximity would make all but the most extreme measures useless in preventing damage to a mineral and gem collection. Limited budgets and constraints imposed by existing storage and display facilities may make earthquake preparedness seem futile. Nevertheless, it is most likely that the earthquakes a collection will experience in the future will be of moderate or lesser magnitude and will be centered a significant distance away. The most effective and worthwhile efforts will be those directed toward preventing damage from these earthquakes. And remember that the greatest and most widespread damage to mineral and gem collections is not caused by any natural disaster, it is caused by human handling.

ACKNOWLEDGMENTS

Mr. Robert Sieger of the J. Paul Getty Museum and Richard C. Erd of the U.S.G.S. provided valuable comments on the manuscript. Dr. Wendell E. Wilson provided the sketches.

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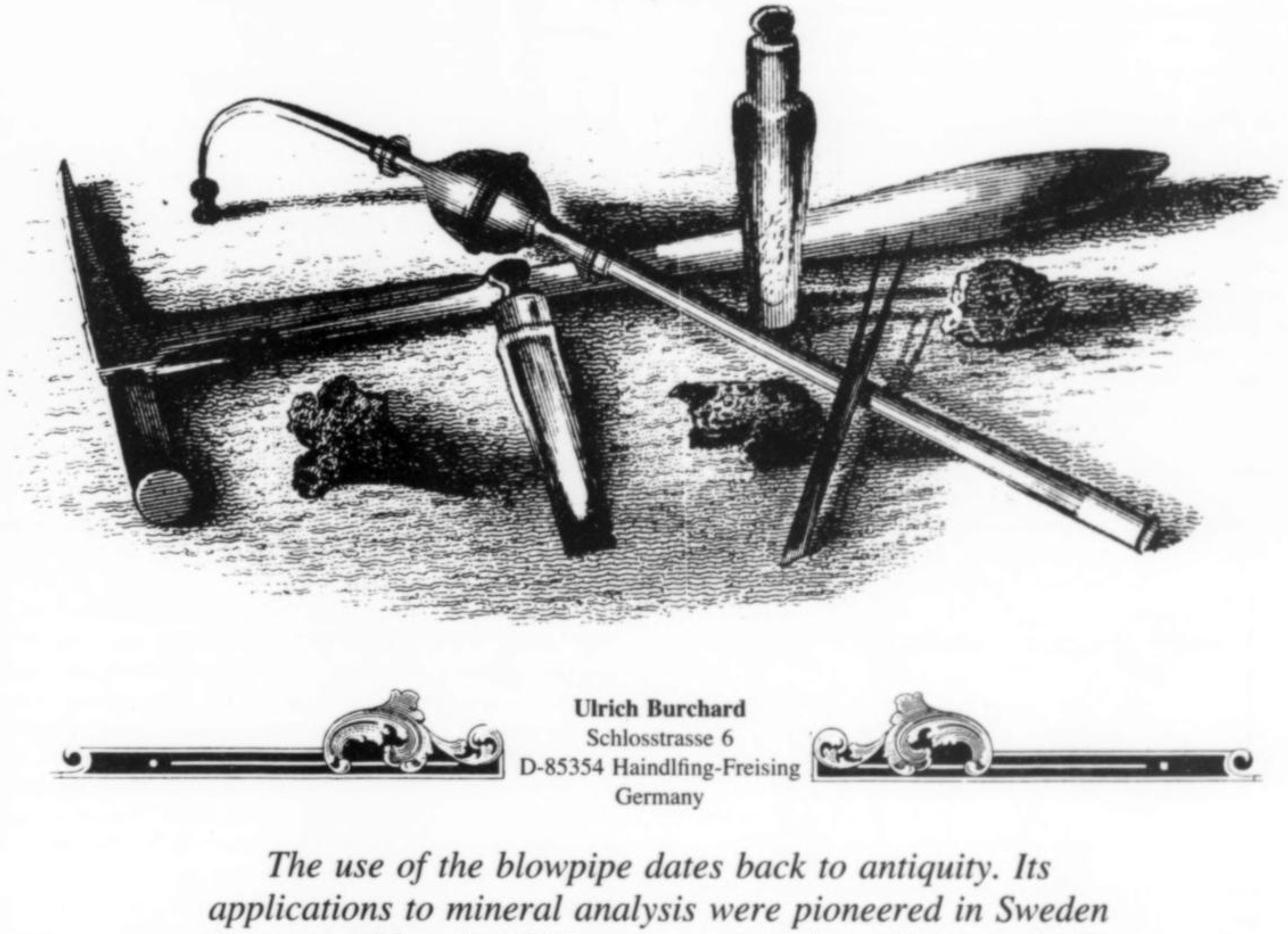
THE HISTORY AND APPARATUS OF BLOWPIPE ANALYSIS



Ulrich Burchard
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The use of the blowpipe dates back to antiquity. Its applications to mineral analysis were pioneered in Sweden by a small band of 18th-century scientists. Their methods were further refined at the Freiberg Mining Academy in the middle-1800's. Blowpipe apparatus was constantly improved and modified until the 1860's, when it was finally replaced by the Bunsen burner and spectral analysis. Many portable blowpipe analysis systems, from small "pocket" kits to full-scale field laboratories, have survived.

INTRODUCTION

In the modern-day education of mineralogists, metallurgists and chemists the study of blowpipe analysis is treated only as an historical curiosity. Today's students are generally unaware of the fact that, through the use of the blowpipe from the end of the 18th century to the middle of the 19th century, the qualitative composition of most minerals was identified and that this device had been instrumental in the discovery of over fifteen elements. Franz von Kobell (1862) described the blowpipe as an instrument that, "in its way, served chemical mineralogy as much as the goniometer served crystallography."

The blowpipe was one of the most important analytical tools for identifying metallic elements by their different physical reactions (fusibility, volume and color change etc.). The instrument is a curved tube, about 20 cm long and provided with a small orifice at one end through which the operator, by using his breath, can blow a stream of air. By directing it through the flame of a candle or burner, onto a small test sample the size of a pepper seed, intense temperatures can be attained that would normally only be expected in a smelting furnace. The reaction in the oxidizing or reducing zone of the flame can be easily observed, with charcoal, clay, glass or platinum serving as the support. The samples are subjected to various tests with the blowpipe and examined with the addition of fluxes and reagents. Most metals may be positively identified by the coloration of the flame, the resultant oxide coating or a fused glass bead. Much experience and talent is needed for efficient work with the blowpipe. Therefore complicated blowing contrivances were developed, sometimes fueled with oxygen or hydrogen to produce the highest temperatures.

HISTORY

The Early Experimentalists

The origin of the blowpipe, through which one could blow a stream of air into a flame to melt metals, is lost in antiquity but was probably an invention of the Egyptians. Depictions of goldsmiths using metal blowpipes can be observed on tomb wall paintings at Sakkara dating to ca. 2,400 B.C. (Singer, 1957). Haughton (1862) shows an illustration of a silversmith that was discovered in a tomb at Theba (dating to about 1,500 B.C.). A blowpipe is also recognizable next to a goldsmith's forge in a fresco from Pompeii (Singer, 1957). It was therefore the precious metal artisans and later the glass blowers who initially utilized the blowpipe to achieve intense heat over a small area.

***Figure 1.* Illustration of an Egyptian silversmith with a blowpipe; Theba, circa 1500 B.C. (Haughton, 1862).**

We owe the very first description of a blowpipe experiment on a fossil to the English physicist Robert Hooke (1635–1703). On the 17th of June, 1663, he studied the physical properties (density, hardness, porosity) of petrified wood. He tried to burn it and, when unsuccessful, he used an alcohol lamp, but stated: "nay, though I kept it a good while red-hot in the flame of a lamp, very intensely cast by the blast of a small pipe" (Partington, 1961).

Erasmus Bartholin (1625–1698), in his famous work *Experimenta Crystalli Islandici Disdiaclastici* (1669), not only was the first to recognize crystal optics but was also the first to perform experiments in crystal chemistry. In his "third experiment," Iceland spar was burnt to lime with the use of a blowpipe. In that same year, 1669, Nicolaus Steno (1636–1686) published his book, *De Solido intra Solidum Naturaliter Contento Dissertationis Prodromus,* also in Copenhagen. It was in this work that the constancy of interfacial crystal angles, at least for quartz, was first described. From this early recognition, Carangeot and Romé de l'Isle (1782) developed the "Law of the constancy of interfacial angles," a fundamental principle in crystallography. Hence, the year 1669 can be regarded as the birth year of crystallochemical science.

ERASMI BARTHOLINI
EXPERIMENTA
CRYSTALLI ISLANDICI
DISDIACLASTICI
Qvibus mira & inſolita
REFRACTIO
detegitur.

ANNO 1669.

HAFNIÆ,
Sumptibus DANIELIS PAULLI Reg. Bibl.

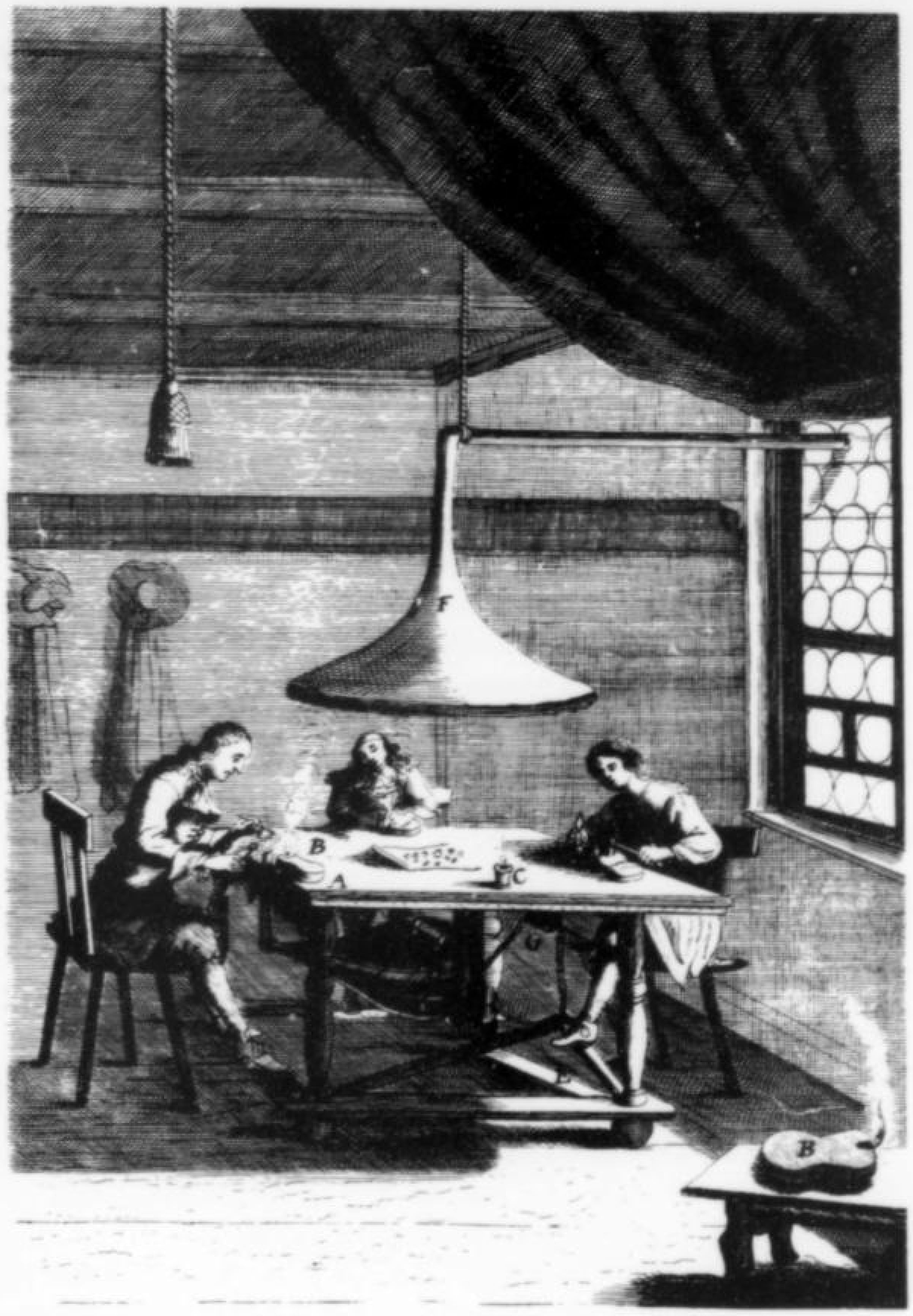
Figure 2.* Titlepage, Erasmus Bartholinus, 1669 *"Experiments with double-refracting Iceland spar."

It is not known whether Steno, who was a physician at the Court of the Medicis in Florence, had obtained his knowledge of the blowpipe at the Accademia del Cimento, and then passed this knowledge on to his countryman Bartholin in Copenhagen. In any case, there is a description in the *Saggi dell'Esperienze Naturali* issued in 1666–1667 in which "The Artificer uses a glass pipe with his own mouth (instead of bellows) upon the flame of a lamp" to manufacture a thermometer.

Johann Kunckel (1613–1703), in his book *Ars vitraria experimentalis oder Vollkommene Glasmacher Kunst* (1679), describes a "tube of pure glass that is bent in the front and has a small nozzle." The air provided by the human lungs or bellows was directed over a candle flame and resulted in temperatures sufficient to melt smaller glass objects. Kunckel recognized a larger potential scope and noted: "There are also some other uses for such an instrument, namely for the chemist." Kunckel mentions charcoal as a support, "in which a small depression is made, the test sample is introduced therein and blown upon using such a pipe through the flame of a strong lamp."

The first to follow Kunckel's suggestions in the use of a blowpipe for chemical investigations was Georg Ernst Stahl (1660–1734). According to Strube (1981), Stahl demonstrated the oxidation-reduction process with the blowpipe in order to confirm his phlogiston theory. Stahl described the action of antimony oxide when heated and reduced on charcoal with a "tubulo caementatorio aurifaborum." In his *Detailed Observations* (1723) Stahl reported about lead oxide:

> If one takes a pea-sized sample, pushes it into a small hole in charcoal and heats it with the light point of a flame produced with a goldsmith's blowpipe, it will melt to glass. When such a glass bead reaches the edge of the coal it will sizzle and in the wink of an eye it will become lead again.

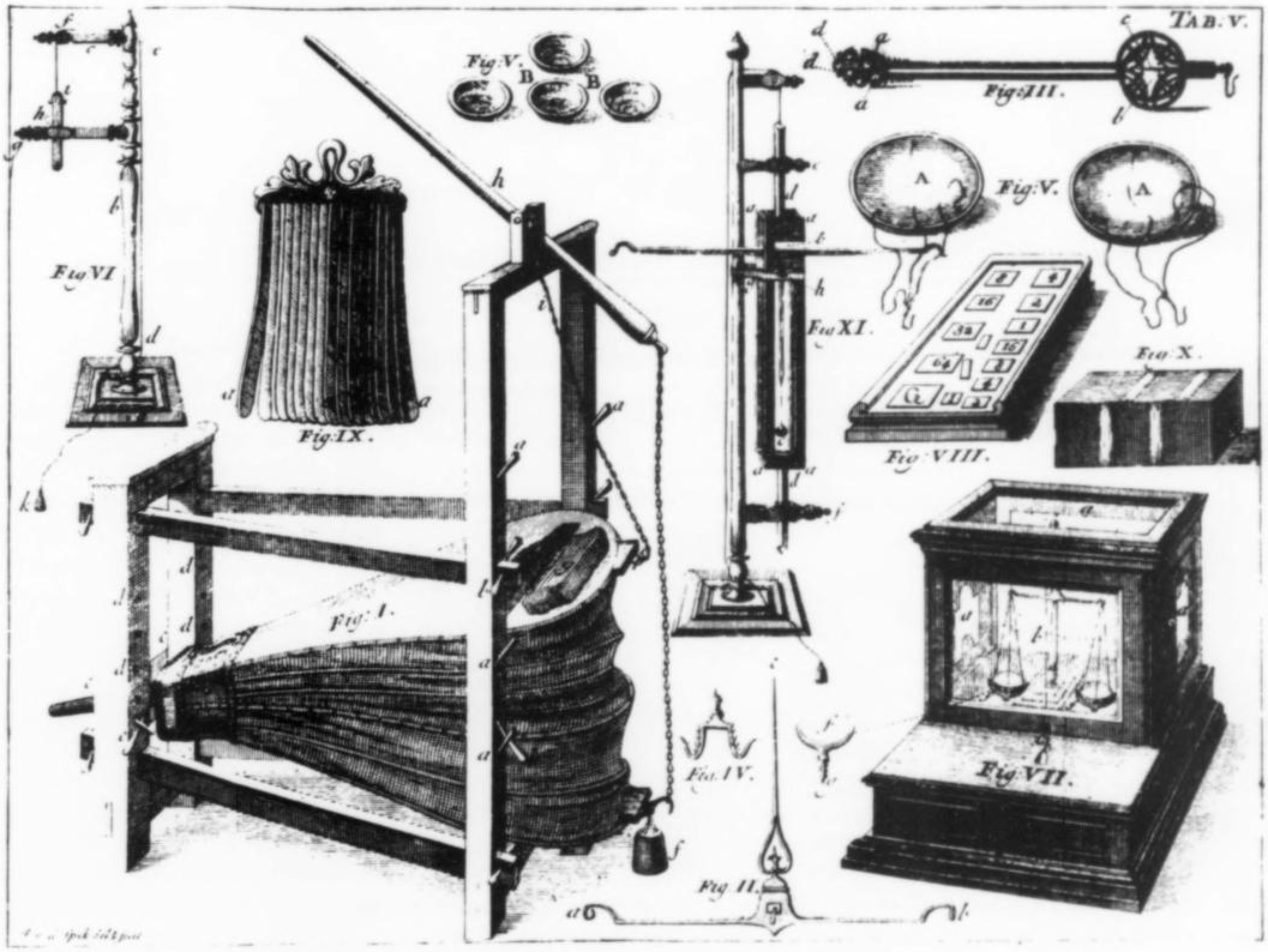


The best mine assayer and metallurgist of his time, Johann Andreas Cramer (1710–1777), recommended that a small quantity of ore be fused with borax on a charcoal support: "quo hoc procedit, si borax additur." In his work *Elementa Artis Docimasticae* (1737) Cramer first described in detail a copper blowpipe (tubus caementatorius) with a hollow ball to collect the saliva. In his later book, *Anfangsgründe der Metallurgie* (1774), all apparatus used in metallurgy and assaying were described. The blowpipe was shown bent and without the moisture chamber. Of particular interest is the drawing of his assay balance within a glass case, that later in the 19th century reappeared in Freiberg almost unchanged.

The discoverer of beet sugar, the Berlin chemist Andreas Sigismund Marggraf (1709–1782), in 1743 revolutionized the production of phosphorous from human urine. His work dealt with "urine from a healthy human, who generally drank beer, and should be collected for a period of five to six months." Through evaporation, filtration and crystallization Marggraf obtained "microcosmic salt." He produced phosphoric acid and pure phosphorous by heating and reduction with carbon. In the *Proceedings of the Berlin Academy* (1746) Marggraf described the action of phosphorus on gold, silver and other metals, as well as his experiments with the blowpipe whereby the phosphorous salt "becomes spherical and eventually produces a transparent glasslike bead on charcoal." Marggraf's "microcosmic salt" became one of the principal fluxes used in all blowpipe analyses.

***Figure 3*. Illustration of a glassmaker's workshop with rape-seed oil lamps, bellows and workers with blowpipe (Kunckel, 1679).**

***Figure 4*. Illustration of an assay balance with glass case, with a view of the lifting mechanism for the balance beam (Cramer, 1737).**



Blowpipe Analysis in Sweden

Particularly in Sweden, the blowpipe was used by mineralogists and metallurgists for quick qualitative tests of ores and smelter products. As in Freiberg at a later period, a school of blowpipe science gradually evolved in which teachers passed on their knowledge to their assistants. Jensen (1986) points out that the numerous publications about blowpipe experiments in the *Transactions of the Royal Swedish Academy of Science* originated from a "small community of chemists, mineralogists and metallurgists, all of whom were part of a common educational and often personal nexus."

Torbern Bergman, in the preface to his book *Commentatio de Tubo Ferruminatorio* (1779), tells us that an Andreas von Swab was the first to use the blowpipe for mineral analysis about the year 1738. Weigel (1790) remarked that the first publication of Anton von Swab, *Regulus Antimonii* (1748), dated ten years later. This work described an ore sample from the Sala mine that was melted with "a small blowpipe on charcoal." Ross (1889) made the assumption that von Swab (also called von Swarb) was the actual author of the *Försök til mineralogie, eller mineralrikets upställning* (1758) published anonymously by A. F. Cronstedt. This view was vehemently opposed by Landauer (1893), who offered the appropriate literary evidence to prove the contrary. However Bergman's reference to Andreas von Swab, who died in 1731 (and consequently could not have performed blowpipe experiments "around 1738"), remains unexplained. It is possible that Bergman confused Andreas with his half-brother Anton (1702–1768) who was a prominent mining expert and Counselor of the College of Mines enobled in 1751. Nevertheless A. von Swab was the first of many Swedish scientists who, together for almost one hundred years, dominated blowpipe analysis.

Two years before Swab's publication, Sven Rinman (1720–1792) mentioned blowpipe experiments with iron-bearing tin ore. In many other treatises he also dealt with the electrostatic and magnetic properties of Brazilian tourmalines. In 1781 Rinman discovered the classic test for zinc compounds, through heating the sample with cobalt nitrate which produces a characteristic green coating (Rinman's green). Oddly enough, it seems that one of the most important chemists of the time, Carl Wilhelm Scheele (1742–1786), could not master the technique of the blowpipe and instead left its use to his colleagues Gahn and Bergman. In a letter dated December 23rd, 1771, Scheele asked Gahn about the action of "brown-stone (pyrolusite) and various metals on the color of glasses . . . because he did not possess the required agility with the blowpipe" (Zeckert, 1934). Scheele's experiments, in which he first discovered the elements manganese, chlorine, barium, tungsten and molybdenum, were mostly wet chemical procedures. In a further letter to Gahn in the autumn of 1774, Scheele wrote that the inner flame of the blowpipe contained more "phlogiston" (oxygen) than the outer. Scheele thus recognized the reducing and oxidizing zones of the flame.

Berzelius (1821) declared Axel Frederik Cronstedt (1722–1765) to be the founder of the chemical system of mineralogy, but stated that he "did not think it necessary to describe in detail the use of the blowpipe." Cronstedt was a first-rate mining expert and was appointed director of all mines in central Sweden in 1748. There was a well-equipped laboratory in the foundries of Skiss. Zenzen (1952) referred to a "Confraternitas Skisshytiana" in which three friends, Cronstedt, Rinman and Bengt Andersson Quist (1726–1799), analyzed minerals. It was at Skiss that Cronstedt succeeded in discovering the new element nickel in ore from Los, Hälsingland. Cronstedt employed borax and soda as fluxes, and knew to use phosphorous salts in the qualitative analysis of characteristically colored metallic oxides (phosphorous salt beads). In 1756 Cronstedt examined minerals from Iceland and Lapland: "In the flame and in front of the blowpipe these foamed and bubbled almost like borax." Because of these properties he named the samples "zeolithes," a word derived from Greek, meaning "to froth, to effervesce." Cronstedt published all of his many experiments on minerals anonymously in 1758. With this he naturally presumed the use of the blowpipe. He was the first to get his results not by accident but by systematic and methodic research.

In 1770 the first *Description of a Mineralogical Pocket Laboratory* by Gustav von Engeström (1738–1813) was published with illustrations and instructions for the use of the blowpipe. This is an expansion of Cronstedt's main work, *Essay towards a System of Mineralogy*

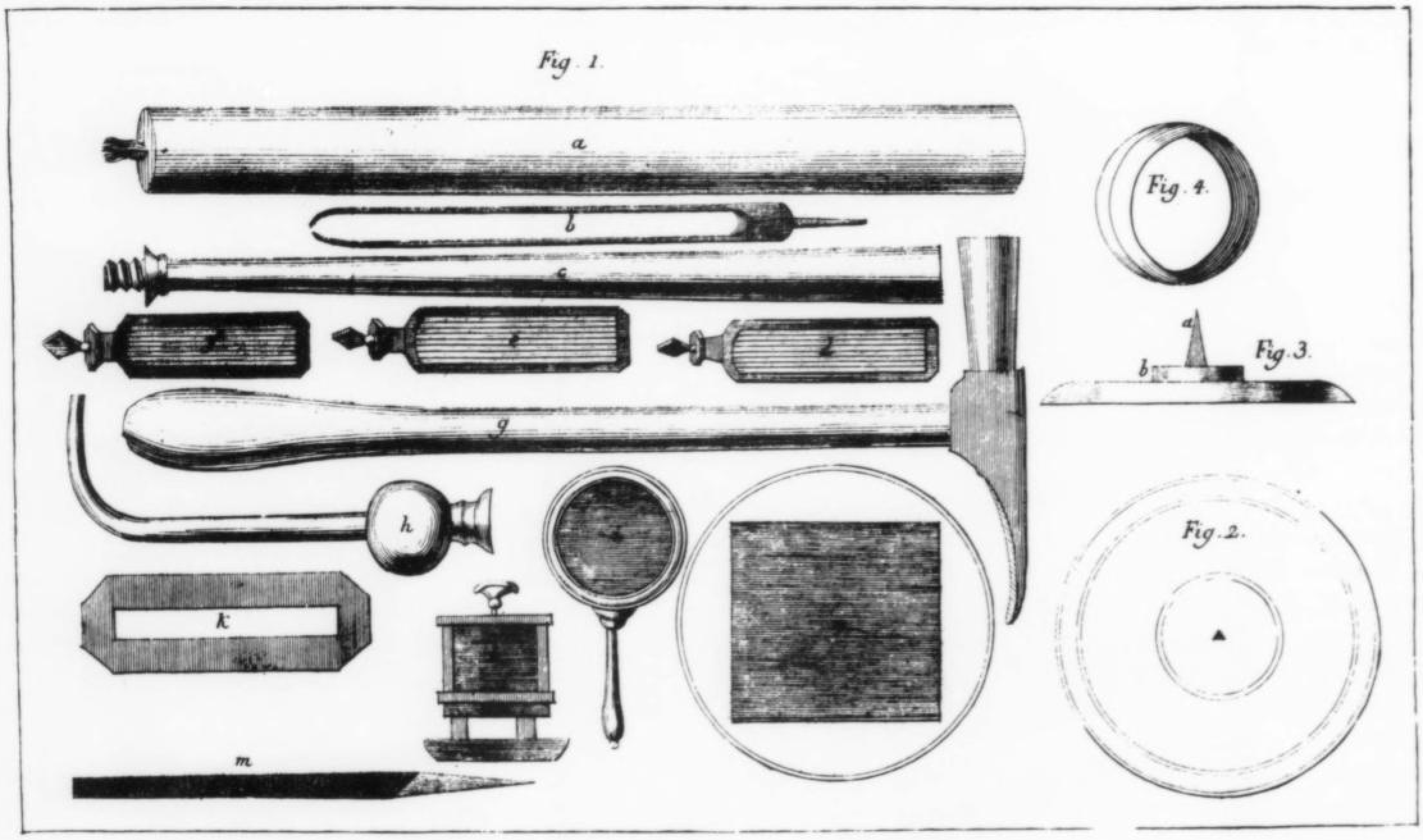


Figure 5. **Components of the mineralogical pocket laboratory of Gustav von Engeström (1770).**

(1758). Engeström praised Cronstedt:

> This talented chemist invented not only a blowpipe but various other items for blowpipe experiments which all fit into a neat, small box which could comfortably be carried in a pocket—especially on travels—so that it could be called a pocket laboratory.

Exactly which tools Cronstedt introduced are not evident.

Engeström's "Pocket Laboratory" was translated from Swedish into German by Christian Ehrenfried Weigel (1748–1831), a professor of chemistry at the Baltic port of Greifswald. It can be assumed that he used all the available 18th-century literature for his numerous comments and footnotes. In 1790 Weigel published his *Versuch einer Geschichte des Blaserohres und seiner Anwendung* ("Attempt at a history and use of the blowpipe"). We can thank him for a full, important list of literature on this topic up to 1790. His work remained unique because there was never a later attempt to comprehensively describe the history of the blowpipe.

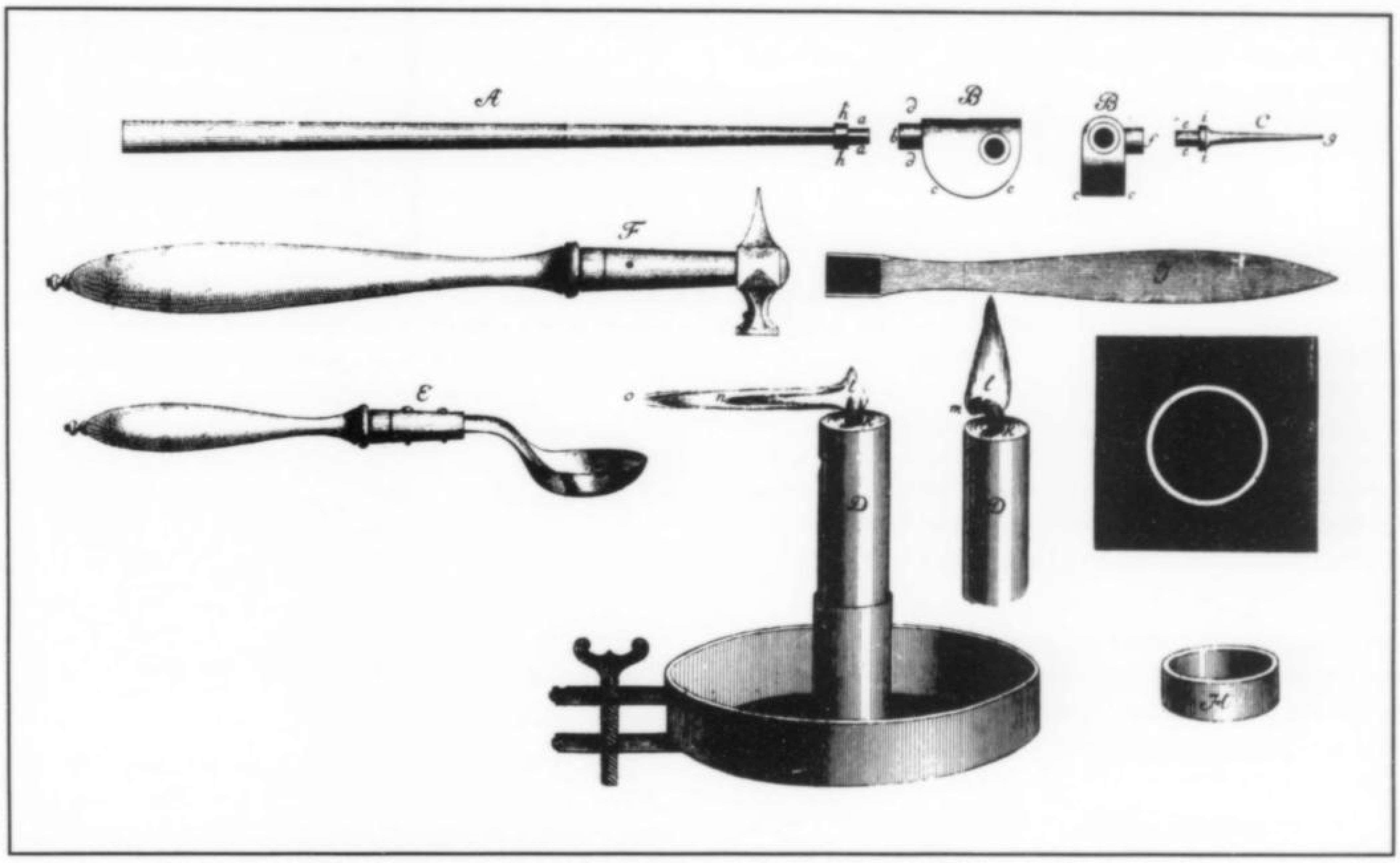


***Figure 6*. Components of the blowpipe kit of Torbern Bergman (1779).**

The Swedish chemical genius Torbern Olof Bergman (1735–1784) published many articles and treatises mentioning blowpipe experiments in passing. These were not limited to minerals but also extended into the field of mineral waters and organic matter. In his main work, *Commentatio de Tubo Ferruminatorio* (1779), a modified three-piece blowpipe made out of silver is described. In addition to charcoal, Bergman also used a silver or gold spoon as a sample support. His portable kit also included an anvil, hammer, specimen pliers and a candle holder.

Bergman's most important student was Johann Gottlieb Gahn (1745–1818), who became his assistant at the chemical institute in Uppsala after 1767. Later Gahn built his own laboratory in Falun. Gahn was acknowledged as an unsurpassed master in the art of blowpipe analysis. Unfortunately he published only a short treatise, *About the Blowpipe* (1820), in which the reactions of various samples with additions of fluxes are described. The intense blue coloration (Thenard's blue), a proof of the presence of aluminum, is noted for the first time:

> Alone, the obvious character of alumina is that it forms a beautiful blue color when mixed with a drop of cobalt sulfate and fused to glowing for a while.

Berzelius wrote about Gahn's devotion to the blowpipe:

> Gahn always carried a blowpipe, even on the shortest trips. Every new substance unknown to him was immediately studied with the blowpipe, and it was interesting indeed to see how quickly and accurately he could determine the nature of the sample. Long before the discussion arose as to whether the ashes of plants contained copper, I have seen that he, out of various types of paper, of which he burnt a quarter sheet to ashes, was able through the blowpipe to extract a measurable amount of copper.

Gahn conceived the most common form of the blowpipe, with an attachable cylindrical saliva reservoir and interchangeable platinum tips. He also introduced the use of platinum wire as a sample support for blowpipe analysis.

Jöns Jakob Berzelius (1779–1848) was probably the most famous of the Swedish chemists. In 1803 he discovered cerium, in 1817 selenium, and thorium in 1828. The chemical symbols in common use today are his. In 1813 he proved the law of constant proportions. Many types of laboratory apparatus were developed by him and, in short, he transformed the alchemistical cellar into a modern laboratory. Berzelius introduced analytical separation using hydrogen sulfide to precipitate metallic sulfides which he then tested with the blowpipe. Every summer between 1812 and 1816 he visited the famous mineral localities in the vicinity of Falun as a guest of Gahn. New mineral finds were instantly analyzed in Gahn's laboratory, and Berzelius learned a great deal of the methodology of Gahn's blowpipe techniques. Berzelius wrote of his teacher: "I had the pleasure to enjoy the company of this most unusual man. He spared no effort to share all his knowledge with me."

During a voyage to England and France in early 1819 Berzelius stayed in Paris. In his autobiographical notes he refers to being urged

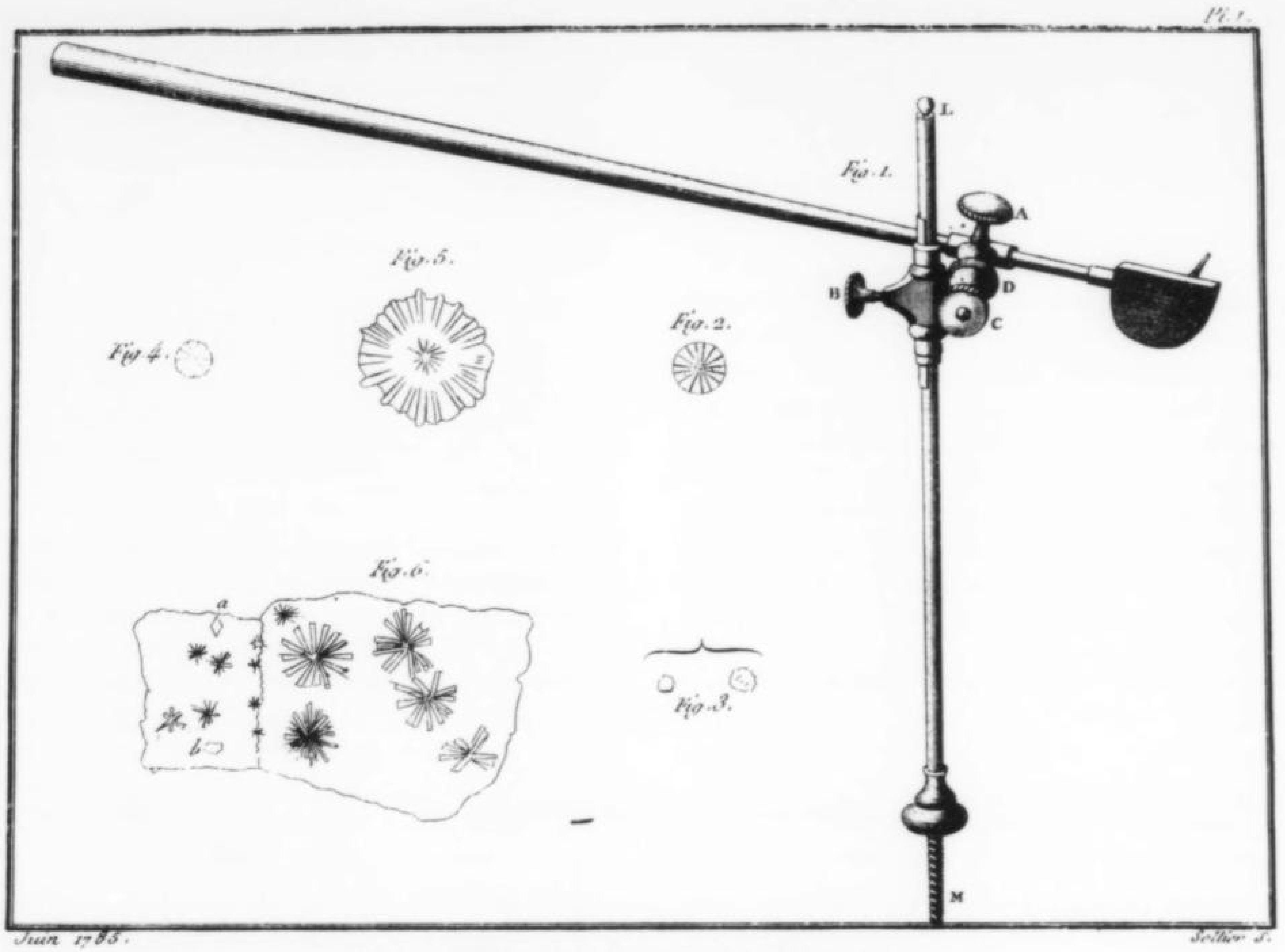


Figure 7. **Illustration of a Bergman-type blowpipe with adjustable holder (De Saussure, 1785).**

to put his vast knowledge of blowpipe analysis in writing:

> In this time I instructed many Parisian mineralogists, e.g. Cordier, Brogniart, Brochant, and Beudant, in the use of the blowpipe and had to promise to write a manual about the use of this important instrument.

He kept this promise after his return to Sweden. In his classic book, *Employment of the Blowpipe in Chemistry and Mineralogy* (1821), all aspects of blowpipe analysis are clearly summarized. In this work Berzelius described in detail seven different types of blowpipe as well as a special oil lamp designed by him. He distinguished four zones of the flame, and used the key words "oxidation" and "reduction" in this context.

In the meantime William Hyde Wollaston (1766–1828) had developed malleable platinum, enabling Berzelius to use platinum dishes, crucibles and spoons for his experiments. For the most part, his apparatus was similar to that of Engeström. New additions included magnetic needles (after Haüy) and further reagents. All implements are contained in a leather rollup. At home he had constructed a special analytical workbench with extendable sides.

Berzelius suffered from periodic headaches, and it was prescribed that he visit the spa in Karlsbad. In 1821 he met with the famous poet and amateur mineralogist Johann Wolfgang von Goethe (1749–1832) in Marienbad, and reported:

> Sternberg and I used the morning to visit the quarry of Hasslau, where there was found a variety of idocrase—the so-called egeran. We managed to bring a few nice specimens to Goethe, which he accepted with pleasure. He then showed me the collection that he had assembled during his excursions, and which were laid out on tables in a special room. They were fairly large but only a few of the specimens deserved to be preserved. We disagreed about the identification of one of the minerals, and, since Goethe did not want to believe me, I suggested we settle the dispute by use of my blowpipe. He told me that he was unfamiliar with the use of this instrument, but would gladly observe its use in some tests. I had a room in the same hotel so I got my apparatus, which I always took on my travels. Goethe was so impressed with the exact diagnosis that I had to identify, by use of the blowpipe, a great number of other specimens he had collected. . . . When I showed him how easy titanium could be determined he complained bitterly that his advanced years would hinder his education in the use of this tool.

In 1822 the excellent analyst made a mistake that he never subsequently acknowledged (Hoppe *et al.*, 1990). Andres Manuel del Rio (1764–1849) discovered in 1801 the new element "panchromium" (later renamed "erythronium") in Mexican vanadinite. Three years later del Rio retracted his discovery because he assumed that the element was chromium. He wrote:

> On charcoal the brown lead ore melts easily before the blowpipe, it smells like garlic during effervescence and reduces into tiny spherules with metallic luster as long it is hot.

A sample of the original type material was brought to Berlin in 1822 by the explorer Alexander von Humboldt (1769–1859). There it was examined by Berzelius, using his blowpipe, and incorrectly identified as chromium. It was only after the 1831 discovery of vanadium in a smelter product from the iron mines in Taberg, Sweden, by Nils Gabiel Sefström (1787–1845), that Friedrich Wöhler (1800–1845)—with the cooperation of Berzelius—also identified vanadium in the lead ore of del Rio. Both Sefström and Wöhler were assistants to Berzelius from time to time. Carl Gustav Mosader (1797–1858), the discoverer of various rare earth elements, also emerged from the Berzelius school and filled many blanks in the periodic table of the elements. The blowpipe always served as an important analytical tool. Jorpes (1966) makes the excellent comparison that, through the efforts of Berzelius, "the blowpipe thus became the stethoscope of the chemist."

Elsewhere in Europe, 1785–1825

In his chapter on the history of the blowpipe, Berzelius wrote: "In the rest of Europe only one, outstanding scientist was engaged in blowpipe analysis: Mr. de Saussure." The geologist and alpine researcher Horace Bénédict de Saussure (1740–1799) was initiated into the art of using the blowpipe by Jean André Mongez (1751–1788). Mongez accompanied Laperouse on his doomed voyage to the South Seas and was never to be heard from again. In a letter to Mongez in 1785 de Saussure described a holder he had designed for the blowpipe. In his experiments with precious stones he dispensed with charcoal as a sample support and instead used glass tubes to prevent the small crystal fragments from blowing away during his experiments. To prevent the substances from melting in with the softened glass he invented a method of soldering fragments of rocks onto highly infusible fibers of "Sappare" (kyanite). De Saussure often observed the fusibility of samples under the microscope. His ultimate goal was to come up with a "scale of fusibility of bodies." He ascertained such an arrangement for 130 mineral species.

William Wollaston invented many useful devices, like the reflecting goniometer and the total reflectometer. In 1806 he designed a blowpipe of three pieces that fit into one another, the largest one the size of a small pencil. Wollaston hardly reported on his blowpipe experiments except in a treatise *On Gouty and Urinary Concretions* (1797). He was accustomed to working with minute sample quantities, and his personal friend Berzelius was surprised to see how small his sample sizes were. Partington (1961) wrote of him:

> Wollaston never admitted even his friends to his laboratory. When a foreign scientist called on him and asked to see this, Wollaston merely showed him a tea-tray containing a blowpipe, some platinum foil, a few watch glasses and some test tubes.

Wollaston and his partner, Smithson Tennant (see below), once purchased a quantity of platinum ore in which they first isolated the new elements palladium and rhodium and later osmium and iridium. In the process of distinguishing between palladium and rhodium the blowpipe was an important diagnostic tool, because rhodium could not be rendered molten due to its high melting point. Wollaston invented a process to produce malleable platinum, and the sale of platinum wire and crucibles became a successful enterprise. His partner, Smithson Tennant (1761–1815), a chemistry professor from Cambridge, was probably introduced to blowpipe analysis by Gahn and Scheele during a trip to Sweden in 1784. Berzelius named a type of blowpipe after Tennant. Tennant gave many lectures on various topics (e.g. borax from the island of Lipari) but published only seven articles, none making any reference to the blowpipe which he was to have designed.

James Lewis Smithson (1769–1829), the founder of the Smithsonian Institution in Washington and son of the Duke of Northumberland, engaged himself extensively with blowpipe examinations of minerals. In 1823 Smithson accomplished a refinement of the Saussure method of fixing most minute particles on splinters of kyanite. He substituted aqueous gum with a mixture of refractory clay and water. His experiments, *On Some Compounds of Fluorine* (1824), are highly important. He remarked:

> Fluor spar has decorated mineral cabinets, from probably the earliest period of their existence, with every tinge with which chance can paint it . . . its true nature continues to be a problem, and its decomposition by fire has yet to be learned.

Smithson confirmed the presence of fluorine in fluorite, topaz and cryolite by heating his samples on a small trough of platinum foil which he placed on the open end of a glass tube. The volatile fluorine was immediately expelled into the glass tube held at an angle. At that time fluorine was detected by the yellow coloration of fernambuk paper. Ironically Smithson's scientific papers also describe *An improved method of making coffee* (1823); this seems to be a well-hidden secret at the Smithsonian Institution.

Edward Turner (1798–1837), a physician, was one of the first to use the coloration of the flame as a diagnostic means. He developed a technology to prove the existence of lithium in hardly fusible mineral species. A mixture of the powdered sample (e.g. spodumene or petalite) was fused with fluorite and ammonium sulfate, whereby a characteristic red color of the blowpipe flame could be observed. Turner also alluded to a technology for identifying boric acid in insoluble silicates using platinum wire. He introduced powdered boracite into the blowpipe flame and it showed a typical green color. Turner identified boron in datolite, tourmaline and axinite by using a special flux (1 part fluorite, 45 parts potassium sulfate). Identification of elements by observation of the coloration of the flame was later refined by Bunsen (see below).

Johann Friedrich Hausmann (1782–1859), a Göttingen mineralogist, gave detailed instructions in his treatise, *Über die Untersuchung der Fossilien vor dem Blas- oder Löthrohre* (1810). He remarked about the size of the sample, its position within the oxidizing or reducing zone of the flame, the choice of support (platinum or silver dish, glass tube, charcoal, or kyanite), the strength of blowing, the type of lamp fuels (oil, tallow, or stearine). Hausmann also used a great many different reagents. With his blowpipe he discovered several new mineral species (e.g. stromeyerite).

At the Freiberg Mining Academy

Wilhelm August Lampadius (1772–1842) is generally regarded as the founder of the long tradition of blowpipe analysis at the Freiberg Mining Academy in Saxony. At the age of 22 he was already professor of chemistry and metallurgy. In 1815 Lampadius established the first lighting-gas factory in Europe to light the amalgamation works in Halsbrücke near Freiberg. In his treatise, *Sammlung practisch-chemischer Abhandlungen* (1797), Lampadius elaborated on his observations of fusibility, volume and color changes, odor and taste of the minerals tested with the blowpipe. Strube (1981) remarked:

> One of the first instructions for qualitative chemical analysis in the 19th century was Lampadius's *Handbuch zur chemischen Analyse der Mineralkörper* (1801). Contained herein one can already recognize the beginning of the principle of systematical analysis.

Eduard Harkort (1797–1835) came to Freiberg in 1826 and was taught the art of blowpipe analysis by none other than Johann Friedrich August Breithaupt (1791–1873). He obviously developed rapidly in his expertise since Breithaupt, in his description of "tautolith," published the results of Mr. Harkort, and both worked closely in their experiments on "osmelith." Harkort developed a method of identifying potassium by blowpipe analysis in which the sample was mixed with nickel hydroxide and borax and fused. A characteristic blue coloration of the glass bead appeared in the presence of potassium. He remarked:

> The reaction is very sensitive, since it could detect the minute amounts of potassium in pericline—one of Professor Breithaupt's new species of feldspar.

Harkort's main contribution to blowpipe science, however, was the introduction of quantitative analysis. In his book, *Die Probirkunst mit dem Löthrohre* (1827), he described in detail the procedures for testing silver samples of minute size. He copied—in miniature—the ancient methods to test large quantities of silver ore in the muffle furnace. In his introduction to the process of quantitative analysis of silver Harkort wrote:

> The travelling metallurgist who is interested in familiarizing himself with the contents of residues and slags of smelter products in order to assess them, does no longer have to rely on the often purposely wrong information of the concerned smelter workers if he knows how to master the blowpipe.

The special implements and tools used for quantitative blowpipe analysis will be dealt with later. Harkort's most essential new invention was the blowpipe assay scale. Its principle is founded on the idea that the diameter of a minute silver button obtained in blowpipe assay is proportional to the weight. Hence the grade of various ores or minerals can be determined. Harkort's original portable kit still exists. According to Richter (1866), Harkort had emigrated to Mexico in 1827; "Pulled into the political turmoil there, he substituted his compass for the sword and helped to fight against Mexico for the freedom of Texas." According to Schiffner (1935), Harkort probably traveled to Mexico in 1828 and became, for four years, manager of the Santa Ana Smelter on the Rio Yavonio. The mill in Socorro was built by him. In 1833 Harkort joined the Mexican revolution and participated in the battles as Chief of the Corps of Engineers. Later he served as colonel of artillery in the Texas army, and died of fever in Galveston in August of 1834 or 1835.

***Figure 8*. Karl Friedrich Plattner (1800–1858), the "Pope" of blowpipe analysis. (Reproduced by permission of the Freiberg Bergakademie.)**

The "Pope" of blowpipe analysis, Karl Friedrich Plattner (1800–1858), was born in Klein Waltersdorf near Freiberg. After studies in high school and at the Mining Academy in Freiberg the twenty-year-old Plattner entered the services of the smelter, where he rapidly advanced from a helper to chief assayer. He was instructed in blowpipe methods and quantitative silver assays by Harkort in 1826. Plattner expanded Harkort's ideas and invented new procedures for quantitative blowpipe analysis for gold, copper, lead, tin and (at a later stage) for nickel, cobalt and bismuth. He augmented the methods by adding wet chemical tests in combination with blowpipe experiments.

His main book, *Die Probirkunst mit dem Löthrohre* (1835), is the culmination of all the knowledge in this field. It describes in unprecedented detail his experiments, arranged by elements, and is generally regarded as the "Bible" of blowpipe analysis. This masterwork of analytical chemistry lived through eight editions until 1928, and was translated into many languages. It was later enlarged and revised by T. Richter and E. Kolbeck. Ross (1875) praised the book:

> If completeness of detail, extraordinary minuteness of research, patient observation, and honest and simple description can combine to make a perfect book, this is surely one of the most perfect books that ever was written.

Although the evidence is lost, it can be assumed that Plattner closely cooperated with W. F. Lingke, who was the Freiberg "mine mechanicus" and founder of the precision mechanical firm bearing the same name. Lingke developed the "Plattner Apparatus," a portable laboratory which was unsurpassed in its completeness and elegant workmanship. Schweder (1877) described Plattner's basic ideas as follow:

> One could conduct all analytical examinations developed by him with a comprehensive, easily transportable blowpipe kit, packed in a case weighing 10–15 lbs. The experiments could be carried out solely with this apparatus anywhere, in a lumberman's hut as well as the teepee of an Indian.

Plattner encouraged the breakthrough of the trumpet-shaped mouthpiece of the blowpipe. For the quantitative analysis of copper and lead he designed a special charcoal holder permitting the roasting of the sample in a clay crucible without having it touch the charcoal. Plattner also originated the idea of mixing charcoal powder with starch and molding the pliable mass into bowls, crucibles and prisms.

Plattner was held in high esteem by Schweder (1877):

> Plattner is a classic in his blowpipe analysis as well as in all his other work, who with a practical view meticulously considered every detail. It would be difficult to improve his method for blowpipe analysis.

In 1842 Plattner was appointed Professor of Metallurgy and Blowpipe Science. He was involved mainly in research on metallurgical processes for gold and silver extraction as well as catalytic conversion of sulfur dioxide to sulfuric acid. Plattner died in 1858; his tomb is preserved at the Donat cemetery in Freiberg.

Hieronymus Theodor Richter (1824–1898) was a student of Plattner and also a master of blowpipe analysis. Richter studied at the Freiberg Mining Academy, had a career at the smelter there and, after Platter's illness, assumed his lectures and exercises. In 1875 he was appointed Director of the Mining Academy. Along with Ferdinand Reich (1799–1883), Richter investigated sphalerite ore from the Freiberg mine, which led to the discovery of thallium in 1861. Richter heated a sample of that ore in a glass test tube and noticed a peculiar color of the coating which was unknown to him. During spectral analytical experiments Reich noticed an indigo-blue spectral line that did not correspond to any of the known elements. Further cooperative research led to the description of the new element indium. Reich and Richter wrote in 1863:

> The reduction of the oxyde on charcoal with soda in front of the blowpipe was proven. It resulted in a soft, ductile metal, with which one could mark a paper, and that was of lighter color than lead, similar to tin.

Schiffner (1935) reported an anecdote about Richter:

> For the 1867 World's Fair in Paris a 1-lb. bar of indium was produced which Richter, a very cautious and timid man, delivered personally. However, he exhibited a lead ingot, externally similar to indium. He carried the genuine indium bar in his boot and secretly showed it only to his scientific colleagues. On his return voyage he hid the bar in a briefcase, and it so happened that he forgot the case, with its precious, irreplaceable ingot, at the customs office in Herbesthal. After a great fright the handbag, with its contents which no one knew about, was returned unharmed.

The blowpipe played an important role in the discovery of a new element for the last time in 1885. At the end of that year an unknown mineral was found on the 459-meter level of the Himmelsfürst mine at Freiberg. Richter analyzed this sample with the blowpipe and determined that it contained 72.5% silver as well as sulfur and "mercury," which was unknown at the Freiberg mines and therefore raised serious doubts. It was left to Clemens Alexander Winkler (1838–1904) to discover the new element germanium after lengthy experiments on the new mineral argyrodite (Ag_8GeS_6), which contains about 7% germanium. Winkler's laboratory is still preserved and is housed in the same building as the famous "Freiberger Mineralien-niederlage." With the discovery of germanium the element "ekasilicium" predicted by Dimitri Mendelejeff (1834–1907) was found and the validity of his "Periodic Table of the Elements" was proven.

Richter also referred to some of the few extensions of the use of the blowpipe beyond the bounds of mineralogy into the "recognition and testing of organic substances." In Erlangen A. van Günther and J. M. Lindner examined many organic (mainly pharmaceutical) substances with the blowpipe, but never developed an analytical system of any consequence. This unsuccessful excursion into organic chemistry demonstrates the high esteem in which blowpipe analysis was held.

The Decline of Blowpipe Analysis

In his *Tables for the determination of minerals by means of simple dry and wet chemical analysis* the Munich mineralogist Franz von Kobell (1803–1882) took the knowledge of blowpipe techniques for granted. In 1837 he devised—analogous to Mohs's well known hardness scale—a six-step fusibility scale and demonstrated how similar mineral species might be differentiated by its application:

1. Stibnite: fuses easily in regular flame
2. Natrolite: fuses only at the lower zone of the flame but easily before the blowpipe
3. Almandine: fuses only before the blowpipe
4. Actinolite: fuses relatively easy before the blowpipe
5. Orthoclase: fuses relatively hard before the blowpipe
6. Bronzite: only smallest fibers can be fused on ends; infusible

Kobell suggested that samples of the minerals in this scale should always be kept handy for comparative purposes.

The displacement of the blowpipe began with the invention of the gas burner by Robert Wilhelm Eberhard Bunsen (1811–1899). It could reach temperatures of 2,350° C; blowpipes and bellows could then be dispensed with. Bunsen's research focused on experiments with the indicative colorations that molten substances imparted to the flame. He developed diagnostic methods for the determination of sodium in the presence of potassium. To differentiate them he used cobalt glass. A hollow prism filled with a solution of indigo allowed him to recognize the flame coloration of lithium in the presence of sodium and potassium.

Bunsen's observations with the blowpipe and gas burner prompted him, in cooperation with Gustav Robert Kirchhoff (1824–1887), to develop spectral analysis (1859). Both recognized that a glass prism dispersed the light emitted by heated substances into a continuous spectrum and that every element was to be identified by characteristically colored spectral lines. Flame spectroscopy and later absorption spectroscopy revolutionized chemical analysis, and the limits of detection were dramatically lowered.

With the aid of spectral analysis Bunsen discovered two new elements: cesium (1860) and rubidium (1861). In order to isolate 7 grams of cesium it was necessary to evaporate 40,000 liters of mineral water from Bad Dürkheim. Later Bunsen extracted rubidium from Saxonian lepidolite. The decline of blowpipe analysis gathered momentum when the Bunsen burner and the spectroscope were introduced to chemical laboratories.

Like Bunsen, Georg August König used a prism of green colored glass for the colorimetric determination of metals. König observed that in the presence of metals that fuse to a green glass in the reduction flame (chromium, vanadium) it is impossible to detect titanium because its red color is complementary to green and therefore invisible. König used these complementary colors for quantitative and qualitative analysis of elements, and called this method "chromometry." For example, a borax bead containing iron turns yellow, one containing manganese turns purple. Both metals together will result in a brown glass with all shades from yellow to red relative to the quantities of these ions. Viewing this bead through a green glass cancels the red color and a pure yellow appears. If the thickness of the green glass is varied by moving the prism, the color change can be used for quantitative estimations, provided that no other complementary color appears in the sample itself.

William Alexander Ross, the author of many books about the blowpipe and "pyrology," was a military officer and seemed to have had strong nationalistic feelings. He tried to prove that London was the birthplace of blowpipe analysis because it was there that Engeström's *Description of a Mineralogical Pocket Laboratory* was first published. Ross complained:

> It seems to me a melancholy fact to contemplate that London, having thus been the parent . . . of "The Mineralogical Pocket Laboratory," should have not only repudiated her fortunate initiation of this important science, but should have used all the power and influence of her many distinguished chemists to crush it and put it down . . . I understand that "The City and Guilds of London Institute" have recently, by the advice of an irresponsible chemist, cut out "Blowpipe Analysis" as worthless from their Curriculum. It is still utterly untaught at "The Royal School of Mines."

Already in 1866 Richter lamented:

> In books dealing with analytical chemistry, blowpipe analysis is generally mentioned, but sadly the instruction in the laboratories is scanty and unsatisfactory.

The proof of the displacement of the blowpipe—which began about 1870—is evident through the citations of contemporary scientists. The publications of later authors, e.g. Balling (1879), Birnbaum (1872), Fuchs (1930), Krüger (1851), Kerl (1877), Landauer (1876) and many others, rarely contained any new aspects and most were only compilations or new editions.

The 1912 discovery by Max von Laue (1879–1957) of the diffraction of X-rays passing through a crystal established the possibility of relating crystal structure to the chemical composition of a mineral. This new, revolutionary method delivered the finishing blow to the use of the blowpipe, which had played such an important role during the century from ca. 1760 to 1860.

APPARATUS

Types of Blowpipes

Berzelius (1821) described in detail seven different types of blowpipe. All are made of metal, usually brass or silver. The length of the pipe normally varies from 20 to 24 cm and should be adapted to the user's eye, so that the sample being tested can be seen most easily. Most mouthpieces were either silverplated or made out of ivory, horn or wood.

The Metal Worker's Blowpipe

The blowpipe as used in its simplest form by metal workers is a tapering conical tube; the narrower end is bent at a right angle and has an opening of about 2 mm. This model has a serious disadvantage in that saliva unavoidably collects and is finally driven out or blocks the jet hole.

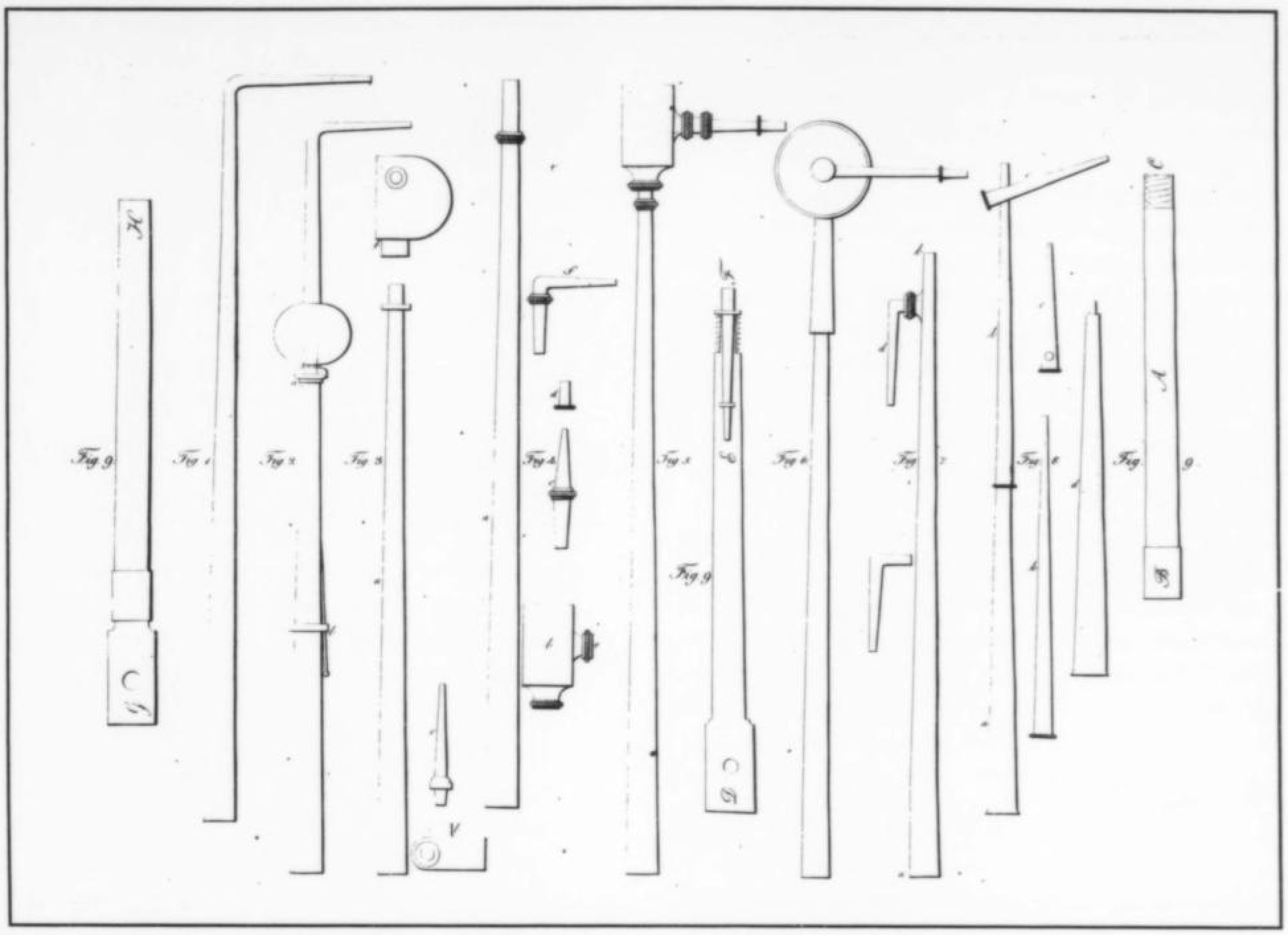


Figure 9. **Illustration of some of the different types of blowpipes as pictured by Berzelius (1821): (1.) Simple, (2.) Cronstedt, (3.) Bergman, (4.) Gahn, (5.) Gahn, (6.) Voigt, (7.) Tennant, (8.) Wollaston blowpipe.**

Cronstedt's Blowpipe

This type was first described by Engeström as an invention of Cronstedt. There is a hollow ball (diameter 2 cm) attached below the middle of the tube; it collects the saliva that would blow out and disturb the flame. Weigel, in his comments on the German translation of Engeström's "Pocket Laboratory," recommended for the first time the use of a trumpet-shaped mouthpiece to facilitate blowing and to avoid tiring the lips. De Magellan (1788) described a minor variation of this type wherein the screw-on connection is located in the middle of the sphere and not shortly above it, as adopted by Engeström. The smaller tube with the jet hole penetrates into the lower hemisphere and is soldered, so that its upper end is even with the "equator," whereas the tube connected to the mouthpiece does not penetrate but is soldered to the surface of the upper hemisphere. In this way the saliva is better confined.

Bergman's Blowpipe

Bergman's "Tubo ferruminatorio" was made entirely of silver and consisted of three parts that could be assembled: (1) the tube, (2) a semicircular hollow disk into the side of which (3) the tip could be inserted. This type could be packed very compactly. De Saussure (1785) used such a form to demonstrate his adjustable holder.

Gahn's Blowpipe

The design which became most popular was proposed by Gahn. The moisture chamber has a cylindrical form (diameter 1.2 cm) and is attached at the lower end of the blowpipe. Small removable platinum tips can be attached with different hole sizes, from 0.4 to 0.5 mm according to requirements. Plattner introduced a mouthpiece made of horn. In his *Gedanken über die vorteilhaftesteste Form des Löthrohrs* ("Reflections on the most advantageous form of the blowpipe") the Swedish engineer Adolph Modeer (1738?–1799) tried various types of blowpipes in a series of experiments and concluded that the cylindrical form of the moisture chamber gave the least resistance to the airstream and therefore was superior to the spherical and disk forms. Since the heat expansion of silver is considerably less than that of copper or brass, Modeer advised that the blowpipe be made out of silver, noting that the treads and tapered parts stayed airtight the longest. In 1823 Lebaillif suggested the addition of a small drain plug in the moisture cylinder to facilitate emptying it.

According to Plattner (1865), Eilhard Mitscherlich (1794–1863), the mineralogist and chemist from Berlin who discovered isomorphism in minerals, modified Gahn's blowpipe for use as a handy traveling instrument. The tube is threaded in the middle and the diameter of the parts is chosen so that they may be stored one inside the other, forming a small cylinder about the size of a pencil. In the compilation of Mitscherlich's works issued by his son, there is no mention of a corresponding published article.

Voigt's Blowpipe

In 1800 Friedrich Wilhelm Voigt (1770?–1803), the "ducally privileged instrument maker in Jena," published his *Beschreibung eines zweckmäßigen und bequemen Löthrohrs* ("Description of a practical and comfortable blowpipe"). The saliva chamber is a flat disk (diameter 2.4 cm), and the blowpipe tip is movable about the central axis. Voigt proposed a holding device for the blowpipe that was adjustable for height. The lamp consisted of a relatively complicated apparatus with six candles arranged in two rows, "with all accessories very neatly made." According to Berzelius (1837), Varley invented a blowpipe with two nozzles of different diameters that were attached to the opposite sides of the disk and aspirated simultaneously. In 1801 a Mr. Pleubel modified the Voigt blowpipe (Krünitz, 1801), so that the mouthpiece was no longer connected to the periphery of the disk but at its base opposite to the screw for adjusting the height on the

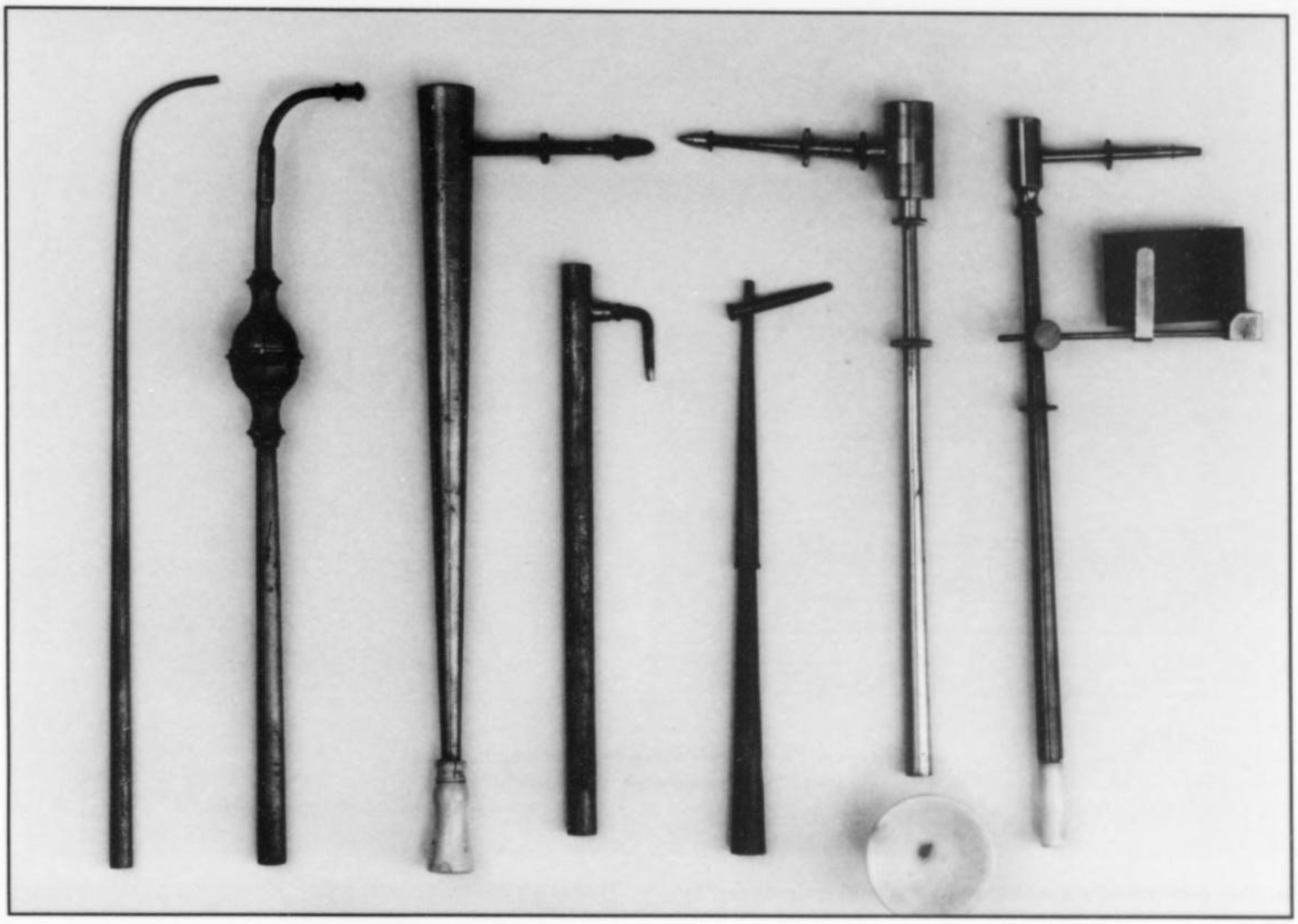


Figure 10. **Blowpipe types (left to right): simple, Cronstedt, Black, Tennant, Wollaston, Gahn, Hirschwald with cobalt-glass.**

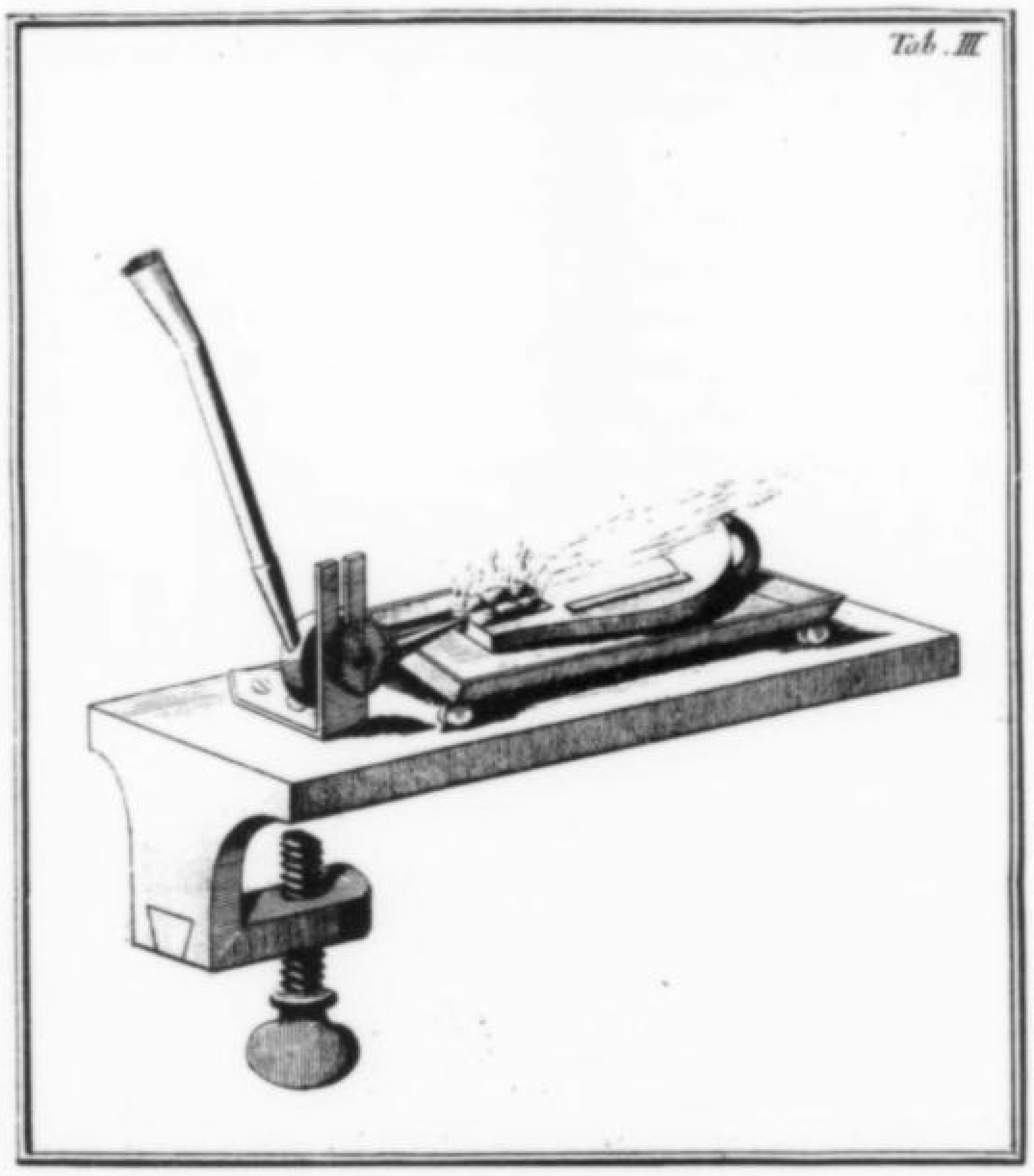


Figure 11. **Illustration of a Voigt type blowpipe with lamp (Voigt, 1800).**

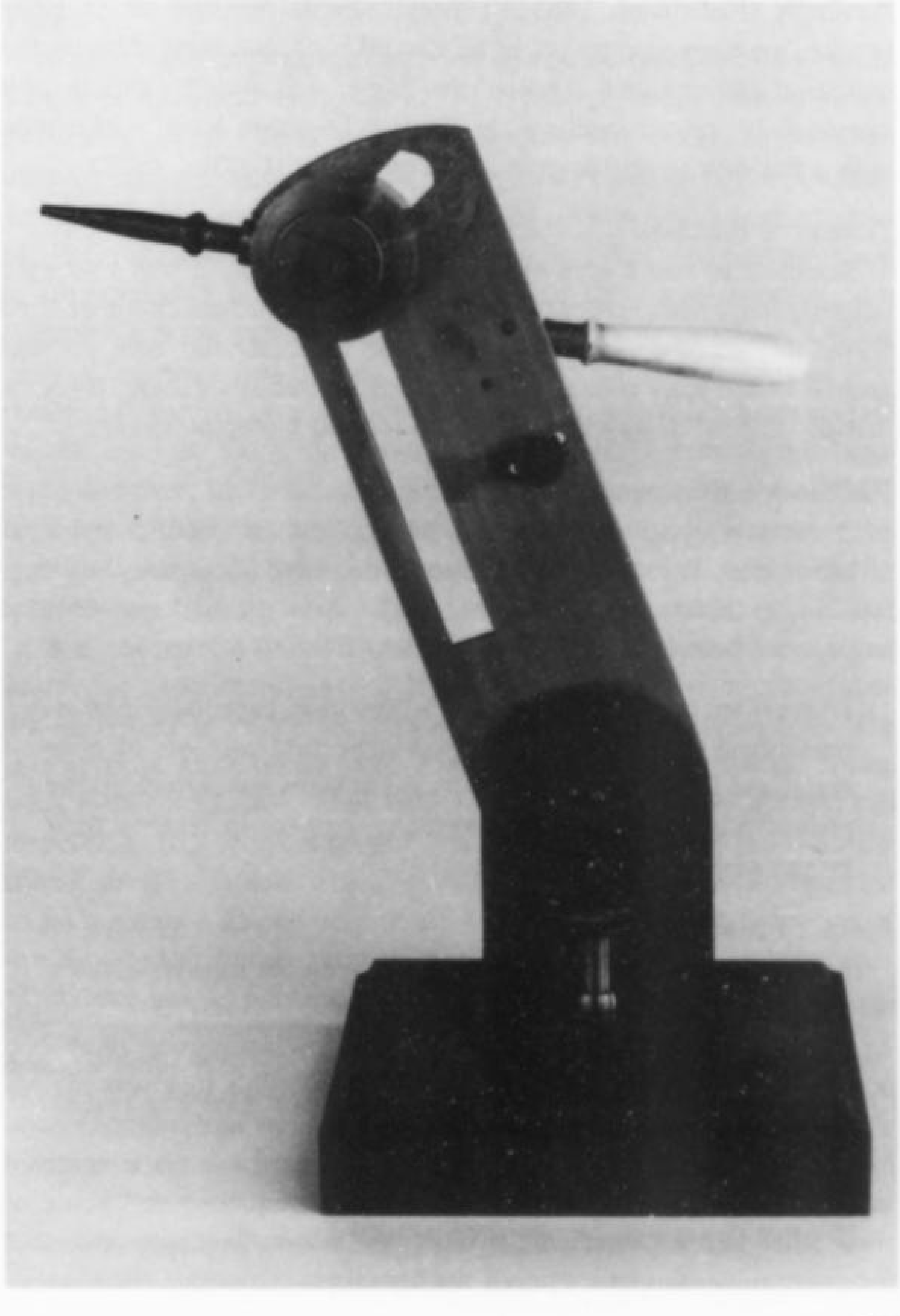


Figure 12. **Moses blowpipe manufactured by Lingke in Freiberg, circa 1865. (By permission of Freiberg Bergakademie.)**

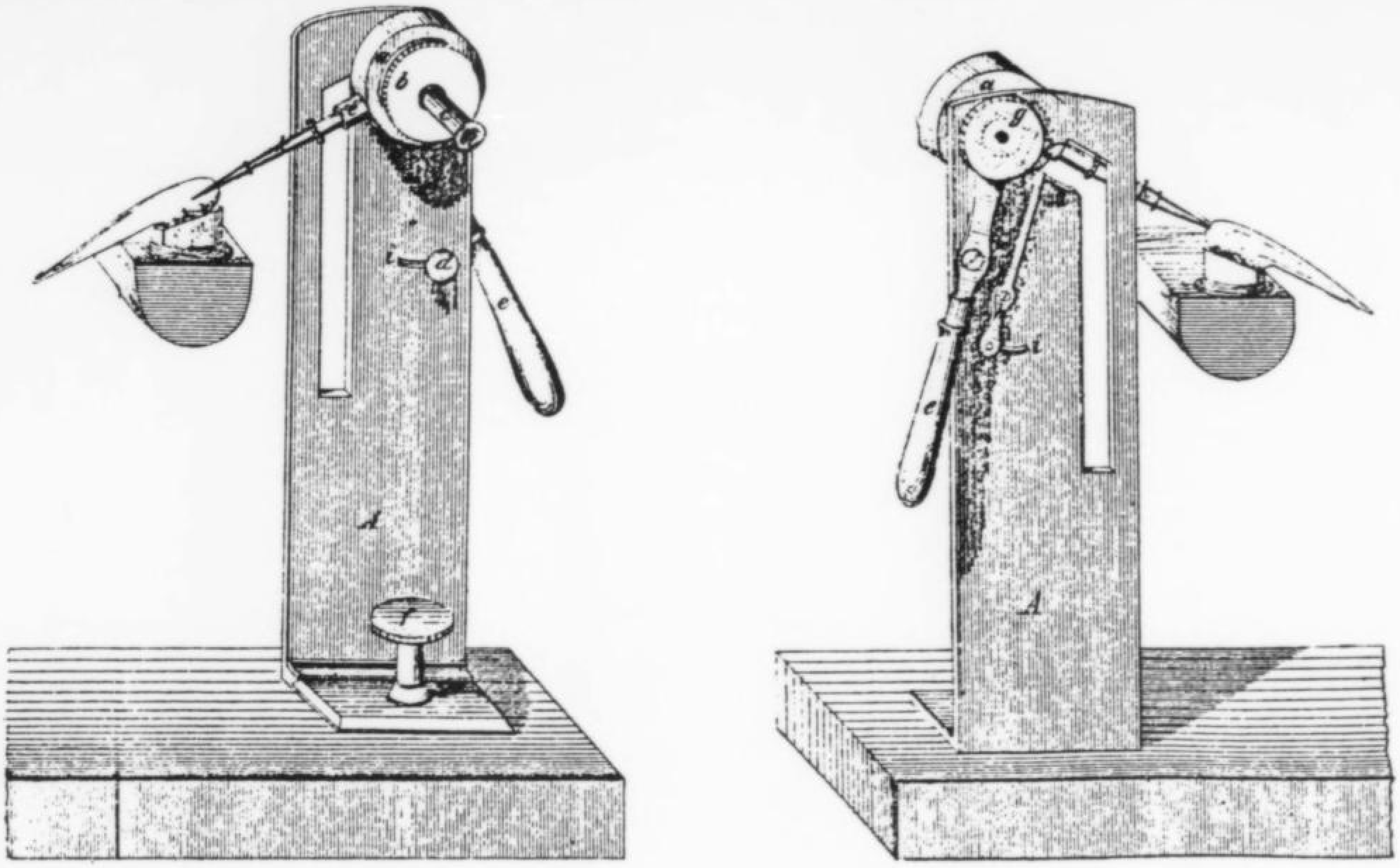


Figure 13. **Moses's blowpipe, showing how the air jet is directed through the flame.**

holder. This principle of a fixed blowpipe was further developed by Mr. Moses, a United States citizen and graduate of the Freiberg Mining Academy (Hoffmann, 1865). Through simple pressure on an ivory handle, the blowpipe tip could be moved back and forth through the oxidizing and reducing zones of the flame. Air could be supplied by mouth or by rubber bellows. In English literature Voigt's blowpipe with a flat disk is also known as a *Pepys* type (Griffin, 1827).

Tennant's Blowpipe

Berzelius named a type of blowpipe for Tennant. It was a straight (slightly narrowing conical) tube without any moisture chamber. Just above the lower closed end of the tube a rectangular bent tip was ground in and fully rotatable. Since Tennant published little, it seems that no original description of this little-used blowpipe exists.

Wollaston's Blowpipe

In 1806 Wollaston constructed the smallest and most portable of all blowpipes. Three conical parts could be stored one inside the other, reducing to the size of a small pencil. The tip is attached at an oblique angle, and there is no moisture chamber. Berzelius described it thus:

> I have often employed Wollaston's blowpipe, especially in pharmaceutical examinations or when inspecting cabinets of minerals, and I have succeeded by its aid in many cases in detecting errors, and assigning to incorrectly named specimens their proper places.

Black's Blowpipe

It seems that Berzelius was unfamiliar with the blowpipe model of the English chemist Joseph Black (1728–1799); in any case he made no mention of it. An illustration and short description was published posthumously by Jacquin and Scherer in 1802. This type was mainly used in England. It is a straight tube that widens at the bottom, and has no moisture chamber but a rounded bottom; the tip is screwed into the side. The original instrument was 30 cm long and made of sheet iron. Black described the blowpipe as an: "indispensable tool for every mineralogist" without further comment.

De Luca's Blowpipe

De Luca (1854) suggested a further modification of Gahn's standard blowpipe in order to bring about a more steady and continuous stream of air. He installed a rubber bellows with a check valve in the middle of the tube. The lungs are used to fill the balloon with air and, because of the elasticity of the rubber, a steady blast of air is expelled through the tip. However direct observation of the experiments was hampered and this type was uncomfortable to handle.

Hirschwald's Blowpipe

A blowpipe apparatus designed by the Berlin chemist Julius Hirschwald (1845–1928) is mentioned in an advertisement by the firm of Dieskau & Company, Charlottenburg, Berlin. Pictured is a Gahn-type blowpipe. Onto the tube is soldered a holder for a cobalt glass filter used for observation of flame coloration.

Blowpipe Bellows

The author of *Pyritologie*, Johann Friedrich Henkel (1679–1747), in his *Kleine mineralogische und chymische Schriften* (1744), had proposed that a bellows should be attached to a blowpipe, and wrote: "You will notice with astonishment how easily and quickly most stones can be melted in a small fire."

Harkort (1827) also invented a relatively complicated apparatus for blowing atmospheric air into a lamp. After 1850, the blowpipe bellows was developed in increasing complexity to produce higher temperatures. Air, ether or alcohol vapors, oxygen and even oxyhydrogen gas were employed. Berzelius (1821) sneers at these contrivances:

> All of these attempts prove that the inventors have no understanding of the proper use of the blowpipe, and one can say that it would be similar to use a bellows to play a wind-instrument. All types of such artificial combinations with blowpipe experiments are useless.

Richter (1866) reached the same conclusion as Berzelius and only approved the rubber bellows for use in quantitative analysis.

Figure 14. **Fuels used in blowpipe analysis.**

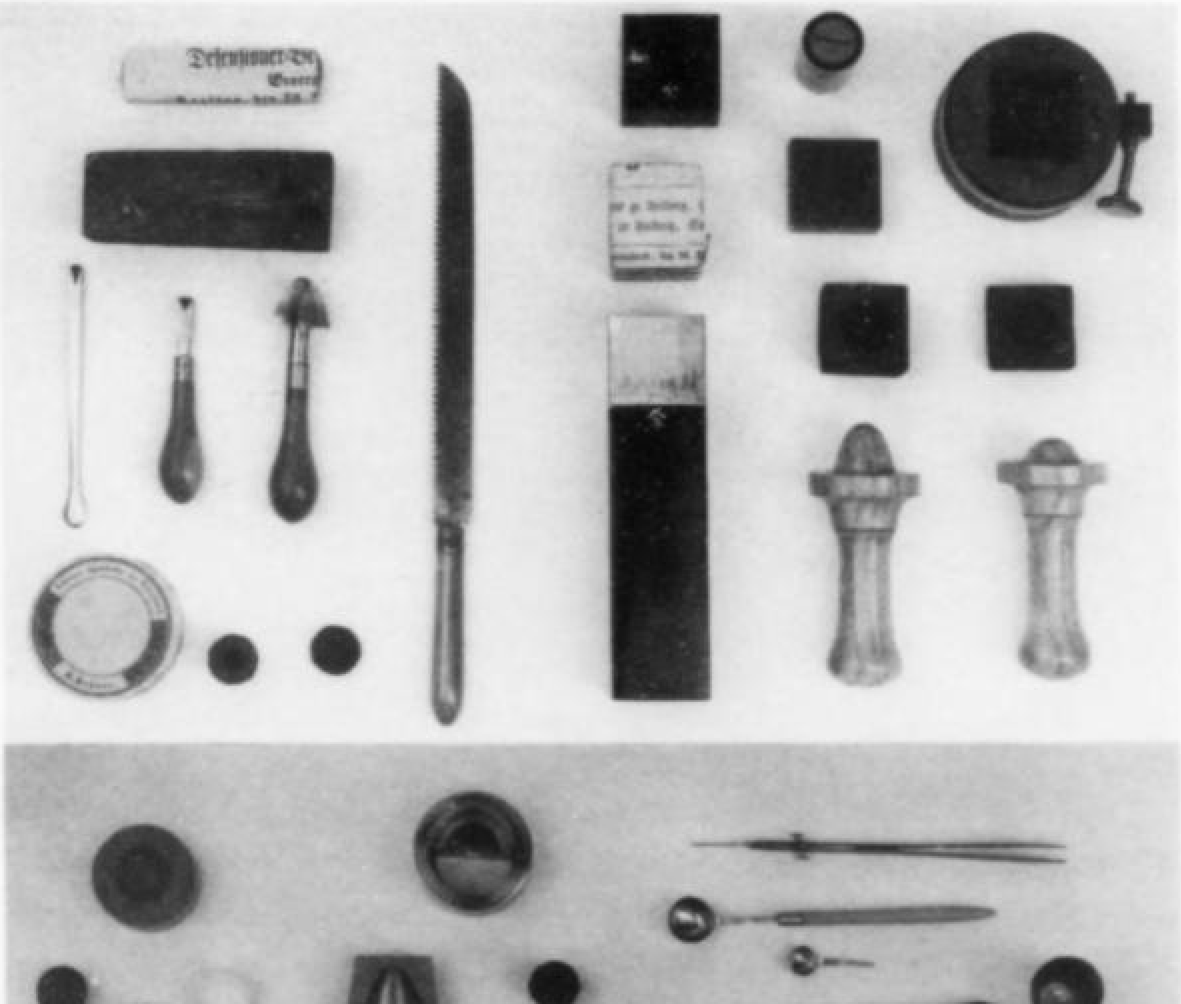


Figure 15. (Top:) **Charcoal supports and tools used in blowpipe analysis.** ***(Bottom:)*** **Clay, platinum and glass supports used in blowpipe analysis, with molds for making crucibles.**

Fuels

In early times blowpipe experimentalists used the flame of a candle with a cotton wick. Bergman (1779, 1784) provided corresponding illustrations. Gahn combined three candles with oversized wicks to obtain a stronger flame. Voigt's lamp (1800) consisted of six candles arranged in two rows. Gahn made use of a lamp which burned olive oil; later rapeseed oil was preferred. It was Berzelius who first proposed an oil lamp with a reservoir made of tinned sheet-iron mounted on a collapsible brass stand and fixed on a brass rod by a screw. On the same stand there was a brass ring with a movable arm with an iron mesh that served as a support for platinum crucibles or porcelain vessels used in drying substances. Harkort (1827) retained this lamp type; however, he installed another opening for refilling the oil, and he beveled the front section of the lamp so that charcoal could be moved closer to the wick of the lamp. The reserve oil was stored in a sheet-iron cylinder tightly closed with a leather gasket.

Berzelius pointed out that it was imperative to use non-sooty alcohol lamps for experiments in which samples were heated in glass tubes and flasks, or in which reagents were fused in platinum spoons. For this purpose glass lamps with ground stoppers and a woven cotton wick were constructed. They were fueled by a mixture of alcohol and turpentine. To lessen the danger of a portable kit leaking fluids during travel, paraffin lamps were also used, however the paraffin had first to be liquified with the help of an alcohol lamp. The introduction of the Bunsen gas burner proved very convenient for blowpipe experiments; the gas jet was slightly modified for that purpose.

Sample Supports

Plattner prefaced his chapter on sample supports as follows:

> In treating an assay with the blowpipe flame, it must be supported on a body which, during the heating and fusion of the assay, will neither combine with it, nor cause wrong results in case the support is combustible.

Coal

Stahl (1703) had used charcoal as an appropriate support. It must be well-burned and is best derived from pine or alder. A charcoal saw helped to prepare elongated pieces or square prisms. Berzelius used a conical iron bit to cut depressions into the coal to hold the sample. Plattner introduced three different coal borers with diameters of 6, 8 and 18–22 mm. Specially shaped charcoal supports were particularly necessary for quantitative assays. These were made out of coal dust and starch stirred in water to form a paste which was pressed into special molds. After drying and heating, the artificial charcoal had the same firmness as ordinary charcoal. Plattner specified several charcoal shapes including flat dish-shaped capsules and crucibles (each measuring 2 cm diameter); the manufacture of these will be described later. These capsules and crucibles could be placed into a cylindrical holder to facilitate handling. This was made out of pumice or fire clay with depressions at each end to hold the charcoal blocks.

For quantitative blowpipe assays a hollow piece of charcoal with a cover is required, which is secured in a special holder. Both square prisms (3 cm) were manufactured in a special four-piece wood mold with a ring clamp and two stamps. These finished charcoal prisms could be safely stored in a tin case.

Clay

For the roasting of samples, clay capsules and crucibles were used. The production of the clay capsules is analogous to the method used for charcoal. One used a paste of cleaned fire clay that was pressed into a boxwood mold with an appropriate stamp of 8 mm diameter. The clay crucibles were formed in a brass mold, consisting of a plug and a box (in German known as "monk and nun"). The box consists of two halves forming a blunt cone with a ring clamp. The plug fitted exactly into the cone and had four openings on the top to release any excess clay. (For the manufacture of large charcoal crucibles a wooden stamp could be used in place of the brass plug.) The finished clay capsules and crucibles were stored in tin boxes. Larger roasting pans of coarse clay were used for roasting and melting.

Precious metal

Bergman introduced silver and gold spoons for experiments in which the reducing environment of the charcoal was not wanted. After 1810 platinum wires, spoons and crucibles were most commonly used. The tips of forceps and tweezers were made of platinum for holding a sample directly into the flame when testing its fusibility. Platinum wire 0.4 to 0.6 mm in diameter was bent into a loop at the end. It was secured by a special ivory or ebony holder. This support served especially in the fusing of borax or phosphorous salt beads and for oxidation experiments. Two different sizes of platinum spoons were employed. The larger (1.5 cm diameter) was used for fusing certain substances and for heating the gold obtained from a quantitative assay. The smaller one (9 mm diameter) served as a tool for the fusion of certain substances with saltpeter. A platinum crucible (3 cm diameter) was advantageous for decomposing compounds of fluorine by sulfuric acid and for igniting filters, the precipitates of which were to be weighed and further examined.

Glass

Glass tubes with a diameter of 6 mm and both ends open served in experiments with substances that became volatile at high temperature by access of air. The sample was placed at one end of the tube and heated over an alcohol lamp. The tube was inclined so as to create a draft through it. The volatile substances sublimed at the upper part of the tube or passed through as gases. Closed test bulbs were mainly used for experiments with samples that decrepitated or contained water. When combustible substances like sulfur or arsenic were sublimed from a mineral, one used a straight closed test tube or one that narrowed so that neither combustion nor partial oxidation could take place as would be caused by a slight current of air.

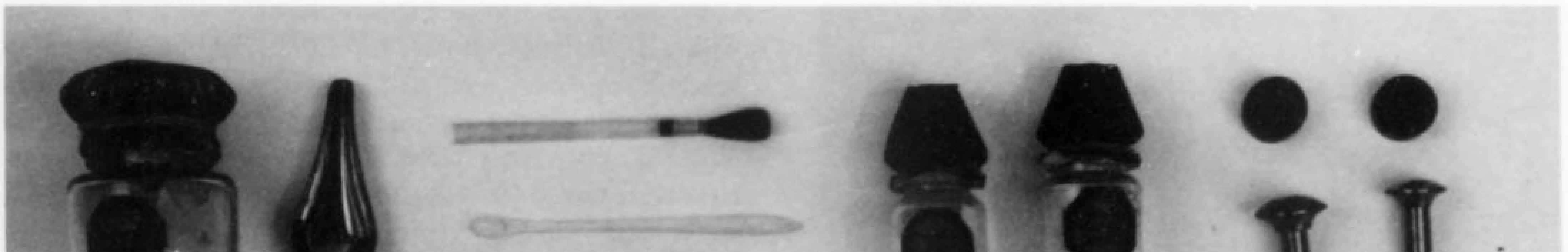


Figure 16. **Implements for quantitative analysis.**

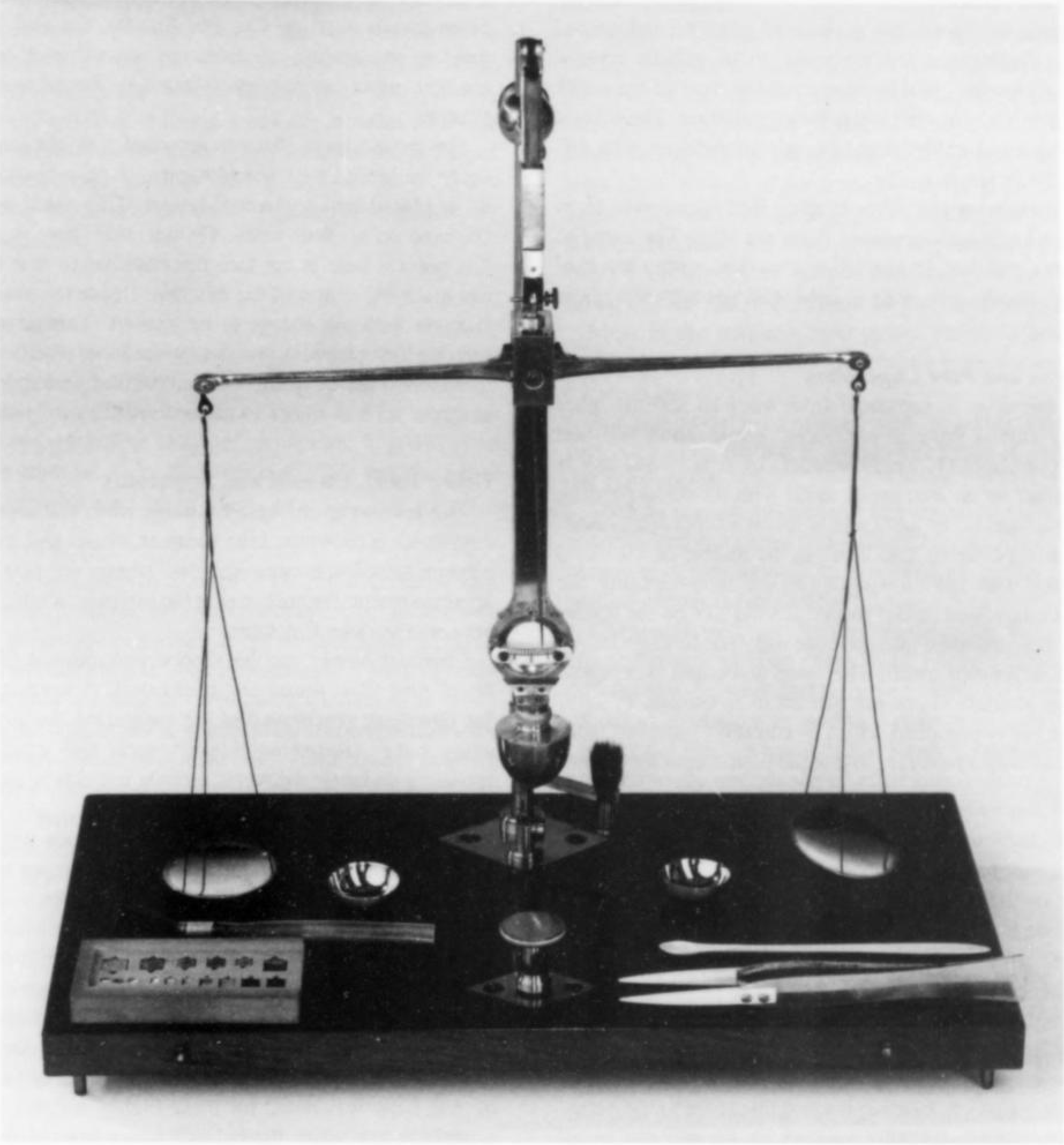


Figure 17. **Collapsible analytical balance, ca. 1870, by Lingke of Freiberg.**

Victor Goldschmidt (1853–1933) used glass plates for his experiments on sublimates, which were particularly useful when studied under the microscope.

Implements for Quantitative Analysis

The quantitative blowpipe analysis of silver was introduced by Harkort in 1827 and further developed by Plattner to include gold, copper, lead, bismuth, tin, cobalt, nickel and mercury. In principle the extraction of pure metal buttons from ores or minerals through roasting and melting is a smelter process. According to Nriagu (1985), cupellation of silver is the "oldest quantitative chemical process known to mankind," probably dating to 4,000 B.C.; it has remained essentially unchanged to the present day. Silver-bearing ore is melted with lead in shallow furnaces (cupels) and exposed to blasts of air. As the cupel is subject to corrosion from the lead oxide it is dressed with bone ash or other porous material capable of absorbing the oxidation products. At the end of this refinement one obtains a small grain of pure silver that can be weighed.

The most important quantitative assay with the blowpipe, that for silver, applies as well for gold or gold-silver alloys. (Gold can only be separated from silver through wet chemical means, with saltpeter or aqua regia.) There are essentially four steps required to perform a quantitative analysis of silver. These will be briefly discussed below so that the use of specific apparatus can be explained in context.

Step 1. Preparation

Preparation of the sample, weighing and charging the assay are the first step. The substance to be assayed must be completely dry; it is reduced in size in a steel mortar and subsequently ground to fine powder in an agate mortar. A sample of one hundredweight (100 mg) is weighed out with an analytical balance. The weighed portion is transferred into a polished mixing capsule and borax-glass and lead are then added. The quantity of borax-glass is regulated by the fusibility of the substance to be converted into slag. The quantity of lead to be used is determined by the presence of other metals in the assay sample; a special test is used to determine the amount of lead to be added. It consists of a glass tube (3.5 cm long) with a wooden cylindrical plunger that exactly fits within. On the cylinder there are gauged divisions so that the amount can be measured by pouring the assay lead into the glass tube with the wood cylinder drawn out to a certain mark. Since varying grain size can influence the volume, the assay lead is sieved and only the fine material is used. After the substances have been thoroughly mixed using an ivory spoon and a polished iron spatula, the charge is poured into a soda-paper cylinder. The later is prepared most easily by wrapping a cut soda paper around a solid cylinder of wood (2.5 cm in length, 7 mm in diameter) and closing one end of the paper. Encasing of the sample in soda paper prevents the charge from blowing away during melting.

Step 2. Fusion of the Assay

The entire package is placed into a charcoal crucible and melted with the blowpipe. During this process some of the volatile constituents, like sulfur and arsenic, will be driven out but most of the easily oxidizable metals join with the lead and melt into a button. The silicate constituents and the metal oxides that can only be reduced with difficulty, fuse with the borax to a slag.

After cooling of the assay the silver-bearing lead is removed from the charcoal with a knife and separated from the slag. The metallic button is placed on a polished steel anvil and worked with a hammer to remove the slag. Finally the grain is held with special steel pliers and beaten into a cube.

Step 3. Scorification and Fine Cupellation

In this process the silver is separated from the lead and the other oxidizable metals. This is done in two steps: scorification and fine cupellation. Firstly a cupel (1.7 cm diameter) of sifted bone ash is struck with a hammer in an iron cupel mold with its corresponding stamp. The cupel remains on its mold and is set on a supporting stand. Then the cube of silver-bearing lead is set in the middle of the cupel and carefully heated with the blowpipe. On the side opposing the blowpipe tip the litharge (lead oxide) forms. It solidifies on the border of the cupel and is also absorbed into the bone ash. The litharge leaves behind a button of silver-rich metal. The same procedure is repeated a second time using elutriated bone ash instead of sifted ash. Finally, a button of pure silver is produced which is carefully removed from the attached bone ash with a tweezer, so that the diameter of the sphere is in no way changed.

Step 4. Weighing

To determine the weight of the silver grain one could use a sensitive analytical balance or the silver assay scale invented by Harkort in 1827. Harkort's scale is founded on the principle that the weights of the metallic spheres are proportional to the cubes of their diameters, and that these diameters can be accurately compared by means of two fine convergent lines, between which the spheres are laid. The prototype ivory assay scale made personally by Harkort still exists. It measures 17.5 cm in length and is divided into 50 lines with plumb weights from 0.0056 to 143.5. Plattner revised this scale to the extent that the silver content from 0.00002 to 3.48 % Ag per one assay hundredweight (100 mg) could be read directly. With the help of conversion charts the analogous gold content could also be determined. The silver (or gold) grain was placed between the converging lines so that it is tangented on both sides. The usefulness is limited, however, since flattening and parallax could give false results. Because of this, Rueger (1869), Kleritj (1870) and Pian (1871) constructed special grain micrometers.

Similar steps are involved in the quantitative blowpipe analysis of other metals such as Cu, Pb, Sn, Bi, Co and Ni. The fluxes and roasting and heating processes are very different however; those readers with more interest are referred to the exhaustive instructions of Plattner.

For these assays Plattner invented a miniature roasting oven that could be heated with the blowpipe. A square charcoal crucible with lid is placed into a charcoal holder. This metal holder surrounds the charcoal on all four sides. On one side there is a small slit, and at this point a hole is cut into the charcoal so that the blowpipe flame can reach the center of the crucible. Inside the charcoal there is a clay crucible with the charge to be roasted. This should never touch the surrounding charcoal, so it is placed on a bent platinum wire such that there is an air space between the clay and charcoal crucibles. The charcoal lid has a hole to allow the escape of volatile gases.

Other Tools, Utensils and Apparatus

The following universally usable tools and utensils are commonly contained in blowpipe kits: hammer, chisel and snippers for breaking mineral samples, a three-part steel mortar and pestle for crushing, and an agate mortar for pulverizing the samples. Knife, scissors and tweezers serve various functions.

Charcoal blocks can be shaped and cleaned of sublimates with a set of files (flat, round and triangular). A hand lens is indispensable for observing reactions and for measuring the silver button with the assay scale. Glazed porcelain vessels and watch glasses of corresponding diameter, beakers, funnels and filters should also be kept at the ready.

Harkort (1827) had an analytical balance among his equipment which was hung on the lamp holder. The balance beam was adjustable in height by means of a silk thread that goes over two rollers. This type of construction has been used since the Middle Ages. Georgius Agricola (1494–1555), in the seventh book of his main work, *De Re Metallica* (1556), provided a description of a grain scale for weighing the silver grains produced in the cupellation process. A similar analytical scale was illustrated by Cramer (1774) and is found in many of the later blowpipe kits produced by Lingke of Freiberg. A precision of ±0.1 mg was noted for these highly portable balances. This was especially true when the balance was protected from dust and drafts by means of a glass case that was also collapsible for travel purposes.

Although blowpipe analysis is principally a chemical science, the early blowpipe kits up to about 1840 contained numerous apparatus to investigate the physical properties of minerals. These can be treated only briefly here:

A ***hydrometer***, reinvented by William Nicholson (1759–1815) for specific gravity tests, was described in great detail by Harkort (1827).

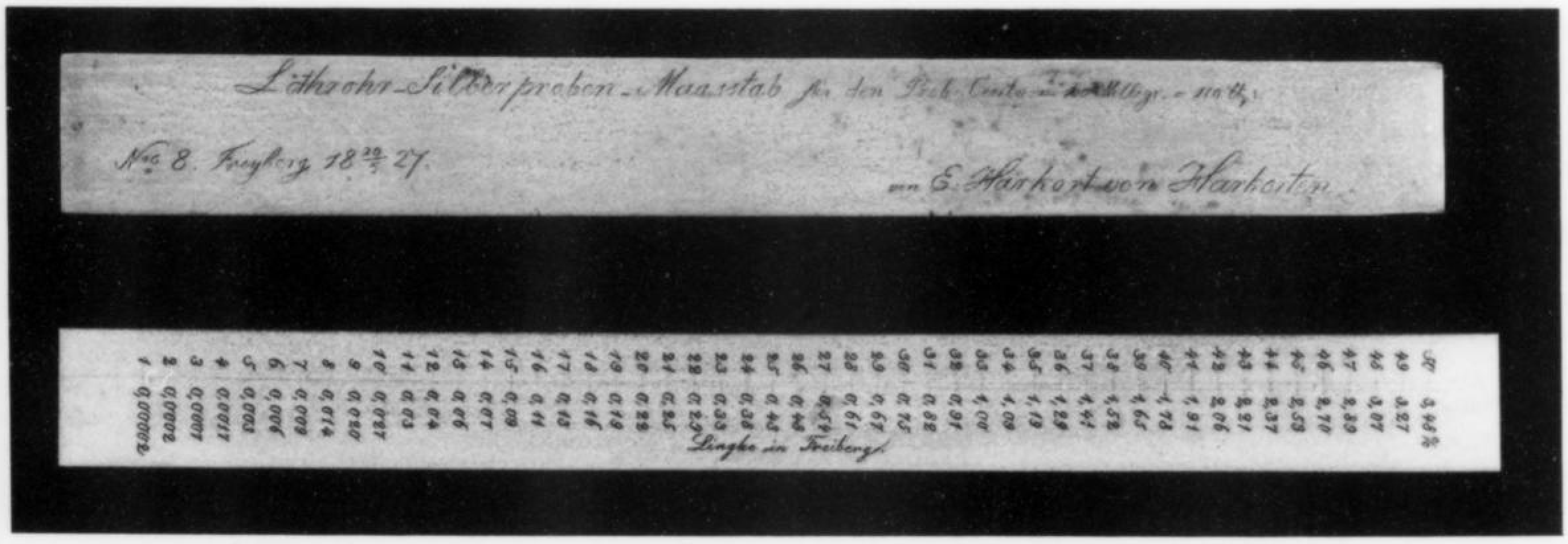


***Figure 18*. Silver assay scales. *Top:* Original by Harkort, dated May 20th, 1827, Freiberg #8. *Bottom:* Lingke, Freiberg.**

Contact goniometers invented by Arnould Carangeot (1742–1786), used for the measurement of crystal angles are often included in blowpipe kits. Engeström (1782) had a brass-cased ***lodestone*** made out of natural magnetite ore in his "Pocket Laboratory." Later, ***horseshoe magnets*** or very sensitive rotating ***magnetic needles*** balanced on metallic points were used to study the magnetic properties of minerals. Similar ***electrostatic devices*** after René Just Haüy (1743–1822) and a cat's-hair electroscope were introduced for electrostatic experiments with minerals.

Reagents and Chemicals

For blowpipe analysis in its classical historical sense only four reagents are used: borax, phosphorous salt, soda and cobalt nitrate. Later, at the beginning of the 19th century, a range of other reagents were brought into use, including saltpeter, potassium bisulfate, and others. Many were introduced by Hausmann (1810) and Berzelius (1821) for special experiments.

Borax ($Na_2B_4O_7 \cdot 10H_2O$)

Borax was already mentioned by Cramer (1737) in connection with blowpipe experiments. It serves as a flux because it combines well with oxides at high temperatures and drives out weak acids (e.g. silicic acid). Borates of the oxides result, which fuse readily. Melted borax containing the dissolved test samples will show characteristic colorations. In experiments with borax it is important to note whether the sample fuses to a transparent or an opaque bead, if the bead is colored, and whether the color changes with alternative use of the oxidizing and reducing flame. Vitrified boric acid is indispensable in quantitative analysis for separating lead from copper and from alloys of the noble metals, which fuse with difficulty.

Phosphorous Salt ($NaNH_4HPO_4$)

Phosphorous salt is the "microcosmic" salt that Marggraf (1746) isolated from human urine. It serves the same purpose as borax by providing colored beads. The glasses which form with the metallic oxides from the sample generally differ in color and intensity from those obtained with borax by similar treatment.

Soda (Na_2CO_3)

Soda is also used as a general flux and serves as a test for sulfuric acid. It promotes the reduction of various metallic oxides. Soda is easily fused, and causes the oxides to mix intimately with the charcoal, facilitating the reduction to metals. These metal grains have to be removed from the charcoal and subsequently examined for streak, hardness, brittleness, etc. The reducing effect of soda can be greatly enhanced by adding potassium cyanide (KCN), so much so that even cassiterite can be decomposed.

Cobalt Nitrate ($Co(NO_3)_2 \cdot 6H_2O$)

Cobalt nitrate is used in aqueous solution to identify several hardly fusible metal oxides, especially alumina and magnesia as well as tin and zinc oxides. Gahn proved the presence of aluminum by the blue color, and Rinman discovered the green color when cobalt nitrate is heated in the presence of zinc. For qualitative assay the powdered sample is mixed with a drop of cobalt nitrate and heated on charcoal. The resulting color of the sample should be observed in daylight only after cooling.

Saltpeter (KNO_3)

Saltpeter serves as an oxidizing agent in melting samples on platinum wires or in crucibles. Manganese and chromium compounds especially result in higher oxidation levels when heated with saltpeter, allowing these salts to be more easily identified.

Potassium bisulfate ($KHSO_4$)

Potassium bisulfate is used for testing halides, lithium and boric acids.

Other Chemicals

Copper oxide (CuO) serves mainly to detect halides. Tin (Sn) is used in ordinary foil and added to phosphorous salt beads to enhance the effect of the reducing flame. Iron (Fe) in the form of wire or filings causes the precipitation of metals from their sulfur compounds and serves in the test for phosphoric acid. Quartz (SiO_2) is used in combination with soda to form easily fusible glass as well as to test for sulfur. Fluorite (CaF_2) and gypsum ($CaSO_4 \cdot 2H_2O$), together with potassium bisulfate, serve to prove the presence of lithium and boron. Other reducing fluxes include charcoal powder, starch, and the so-called "black flux," a mixture of flour and potash.

Most of the reagents used in dry chemical analysis are stored in small wooden cylinders; a glass bottle is necessary only for the cobalt nitrate solution.

The equipment is completed with the addition of certain test papers such as litmus and brazil wood. The latter is used especially in the test for fluorine.

With increasing influence of wet chemical experiments in blowpipe analysis, recommended and furthered especially by Plattner, acids and caustic solutions as well as precipitating agents came into use as in regular chemical laboratories.

Chemicals with very limited applications were used for very specialized reactions. For example, a tincture of gall-nut was used to differentiate between tantalum and niobium. Platinum chloride, dissolved in alcohol, was used as a reagent to identify potassium in the presence of lithium and sodium. Readers interested in this subject are directed to the abundance of experiments described by Plattner.

For training students and for comparative purposes, collections of powdered mineral samples were often provided. The best known set is the one by Plattner, which consists of 106 minerals in tin cases and 110 dry chemicals in glass bottles.

Analytical Procedure

The following general procedure and rules for qualitative analysis were prescribed by Plattner:

Step 1. Examination of the Sample without Reagents

This is carried out mostly in open or closed glass tubes or on charcoal. The behavior of the substance before the blowpipe, its fusibility in the oxidizing and reducing flame, its color changes and the color of any resulting sublimate are carefully observed. If no positive qualitative identification can be achieved it is necessary to resort to step two.

Step 2. Examination of the Sample with Reagents

The most important reagents are: borax, phosphorous salt, soda, cobalt nitrate and potassium bisulfate. Normally the substance to be tested is pre-roasted on charcoal, and then placed on platinum to be further examined with one reagent or a combination of several reagents. Most important of all are the colors of the molten glass beads. Victor Goldschmidt (1853–1933) designed a panel with small artificially colored glass slabs that resemble the color of beads produced in blowpipe analysis with the addition of borax or phosphorous salt in the oxidizing or reducing flame.

Development of Blowpipe Kits

The first *Description of a Mineralogical Pocket Laboratory* was published by Engeström in 1770. The entire kit is stored in a flat wooden box (3 by 15 by 21 cm) and consists of: a blowpipe of the Cronstedt type, wax candle with candle holder, hammer, loupe, magnet, files, steel tool for hardness testing, anvil with ring, and three glass bottles for storing borax, soda and phosphorous salt. The arrangement of these items in the box is sketched in Table 2 of Engeström. It is not known whether a kit of this type survives today. Engeström mentions that a silver spoon, glass flasks, charcoal, wooden trough and three more bottles for reagents were fitted into a second box with the same dimensions.

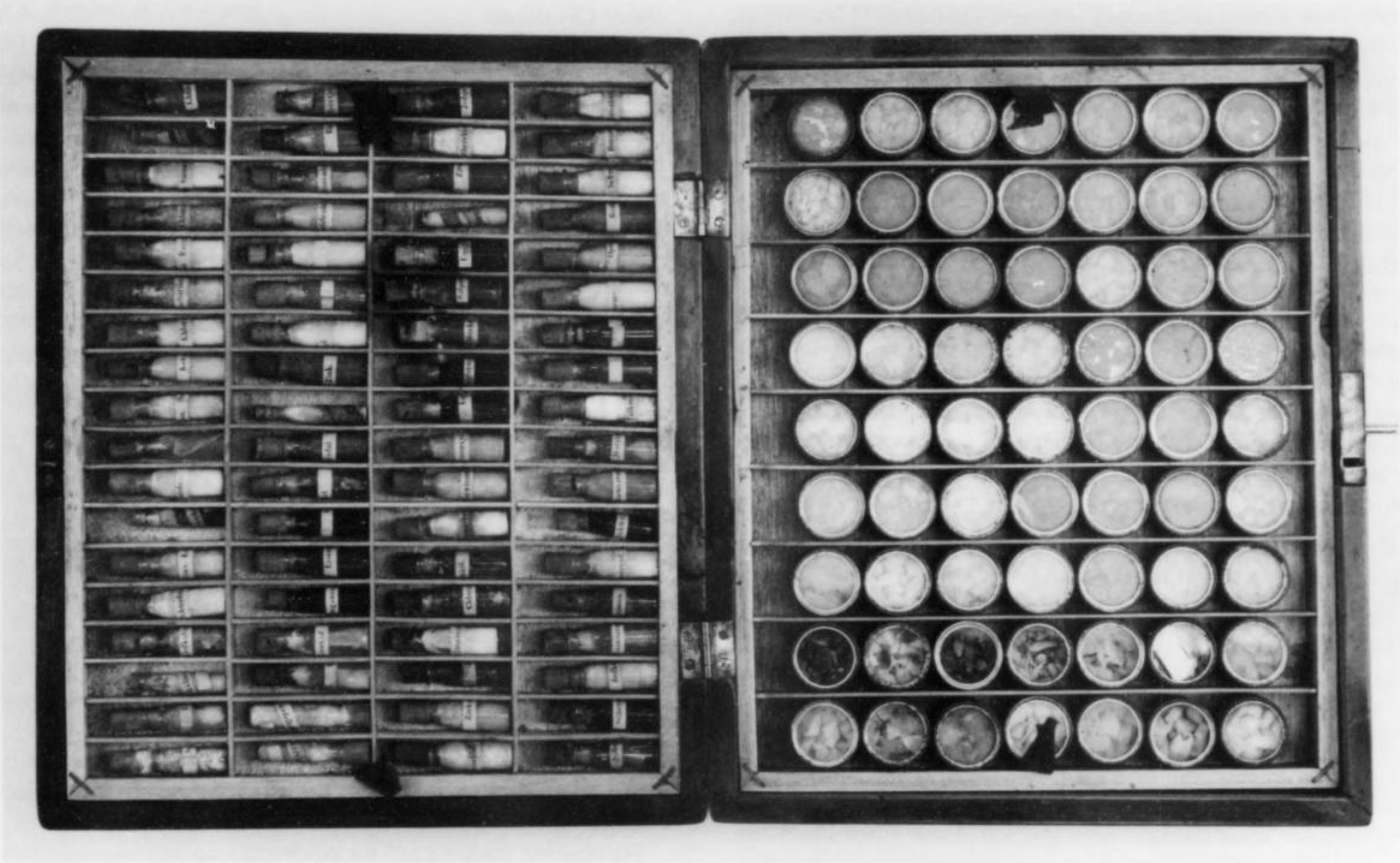


Figure 19. **Collection of reference minerals and reagents, circa 1870, probably issued by the Freiberg Bergakademie.**

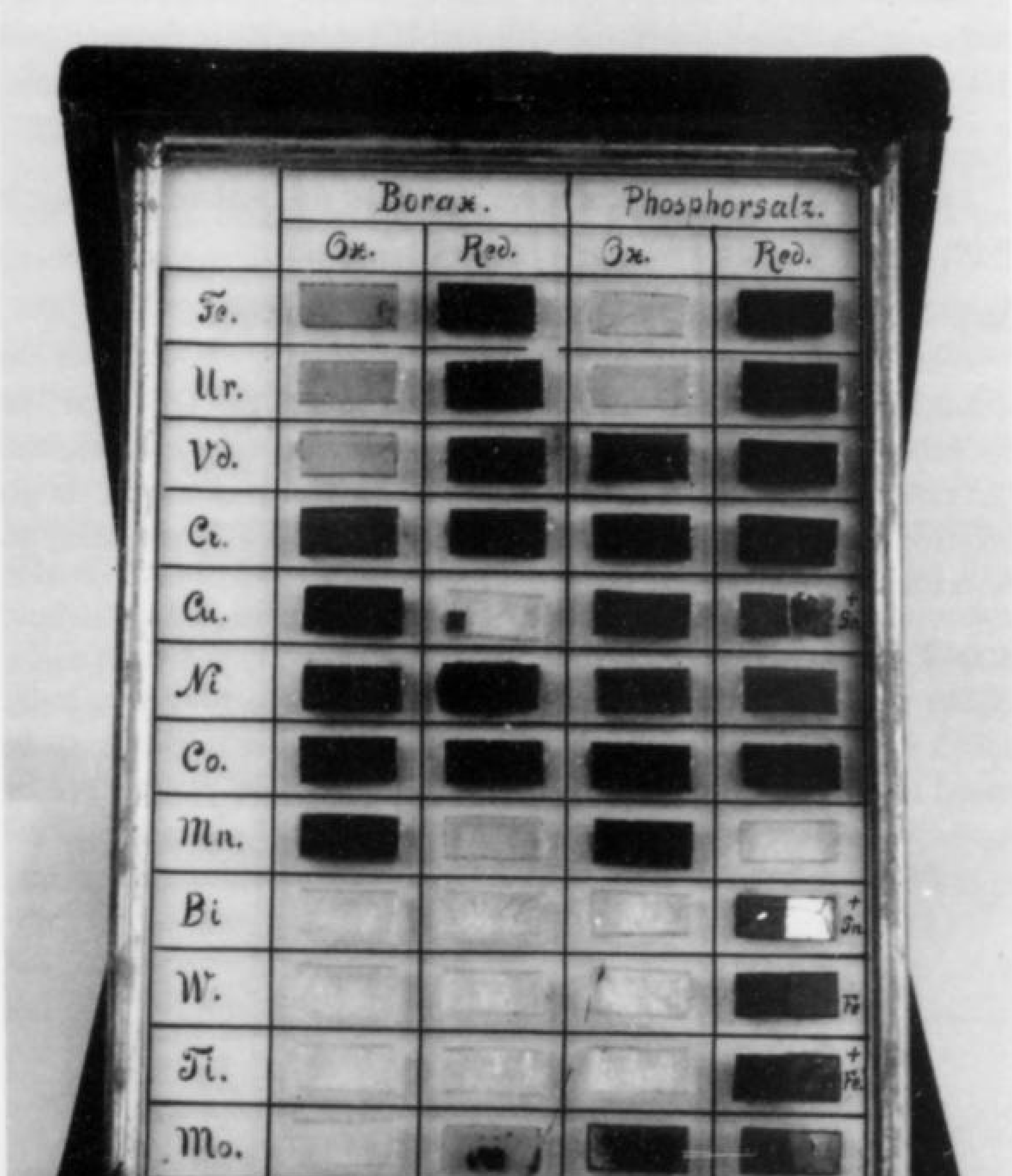


Figure 20. **Panel with colored glass for comparison with colors of fused glass beads. Stoe company, Heidelberg, ca. 1910. (With permission of Freiberg Bergakademie.)**

The blowpipe equipment used by Bergman is still preserved at the Geological Institute of the University at Uppsala. It differed little from the one described above, but the type of blowpipe had changed.

In 1781 Bergman's book, *Employment of the Blowpipe,* was translated into French by the Dijon chemist Louis Bernard Guyton de Morveau (1737–1816). It is obvious that Guyton was inspired by the Swedish pocket laboratories because in 1783 he published his *Description et usage du nécessaire chymique.* With this as a guide one could perform both blowpipe and wet chemical experiments. All instruments and chemicals fit into two wooden boxes the size of a book (4 by 10 by 17 cm). The first one contained six glass bottles for acids, the second box the blowpipe, tweezers, a noble metal spoon, a magnetic needle on a point, a steel blade for hardness tests, and the three standard fluxes: soda, borax and phosphorous salt.

In 1790 Johann Friedrich August Göttling (1755–1809), a pharmacist and chemist from Jena, described his *Vollständiges chemisches Probir-Cabinet,* which also consisted of two wooden boxes (23 by 23 by 30 cm). The first housed 14 glass bottles and a mortar, the second held 21 bottles, a small balance, a pestle and a blowpipe. Göttling's experiments were all of wet chemical nature. He obviously had planned a second volume on dry tests but it was never published.

Karl Cäsar von Leonhard (1779–1862) was the publisher of the *Taschenbuch für die gesamte Mineralogie,* one of the earliest mineralogical periodicals. In 1803 he published a nine-page leaflet, *Anleitung zum Gebrauch des gemeinen Löthrohrs.* This text was conceived as a "supplement and explanation of the pocket laboratory for traveling mineralogists experimenting with the blowpipe." This small kit contained: a blowpipe, anvil, hammer, silver foil, tongs and three bottles for the "most superior fluxes."

During the first third of the 19th century, simple and comprehensive mineralogical analysis kits were made, especially in Britain and France. Besides the blowpipe utensils and some reagents, these often contained a contact goniometer, hydrostatic balance and some mag-

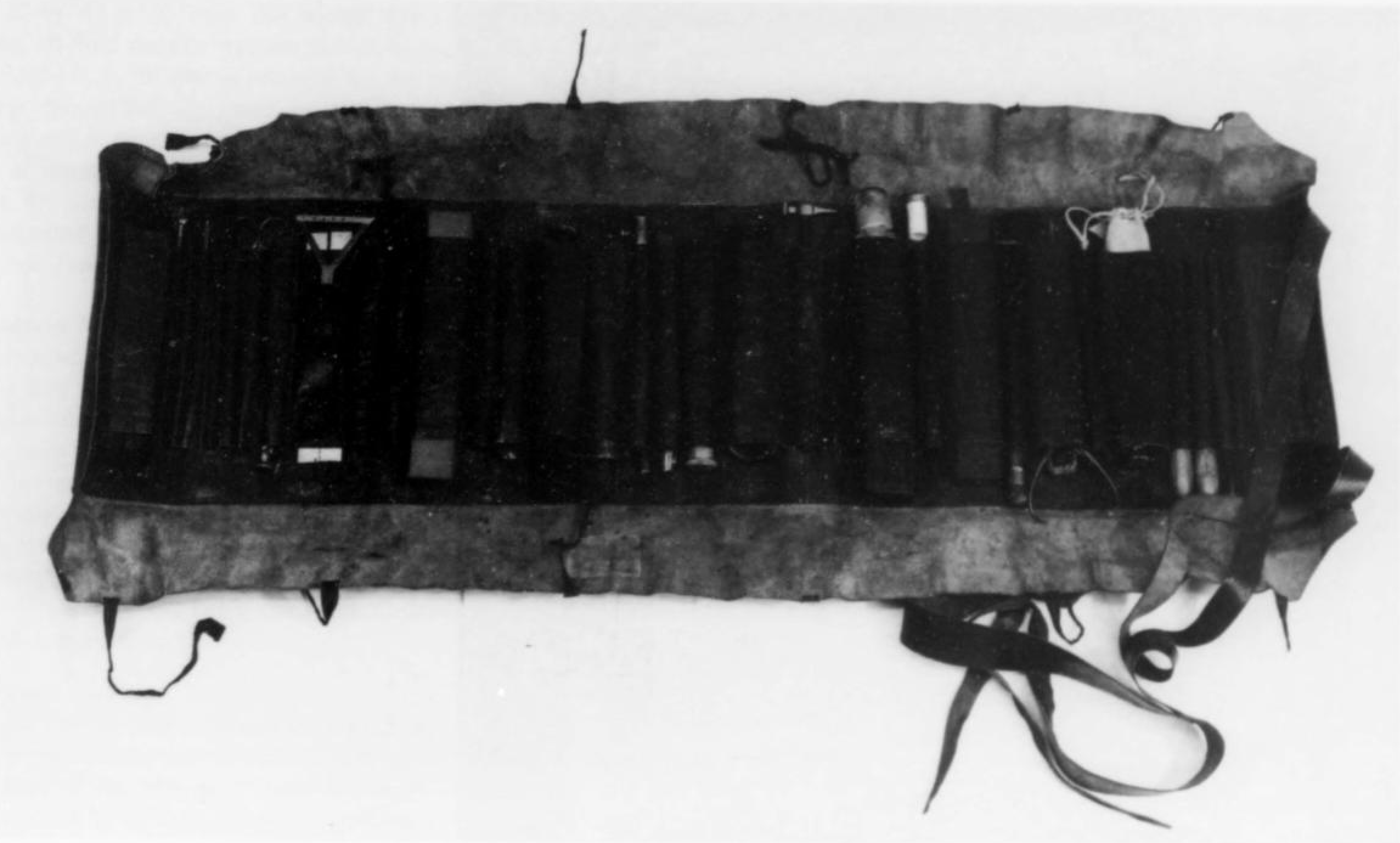


Figure 21. **Original blowpipe leather rollup of Berzelius, ca. 1821.**

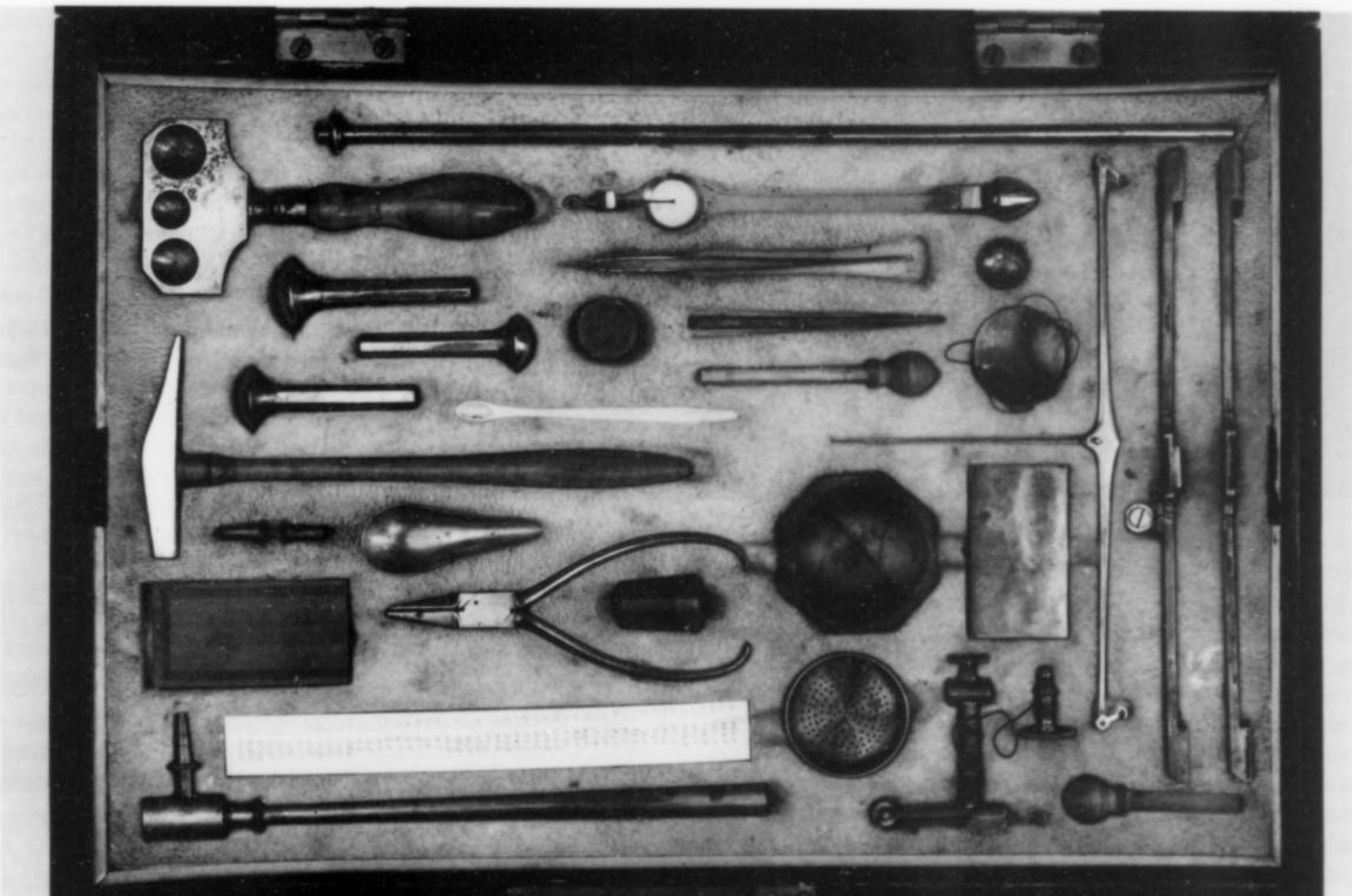


Figure 22. **Harkort's original blowpipe kit, manufactured by Lingke of Freiberg in 1827. (With permission of Freiberg Bergakademie.)**

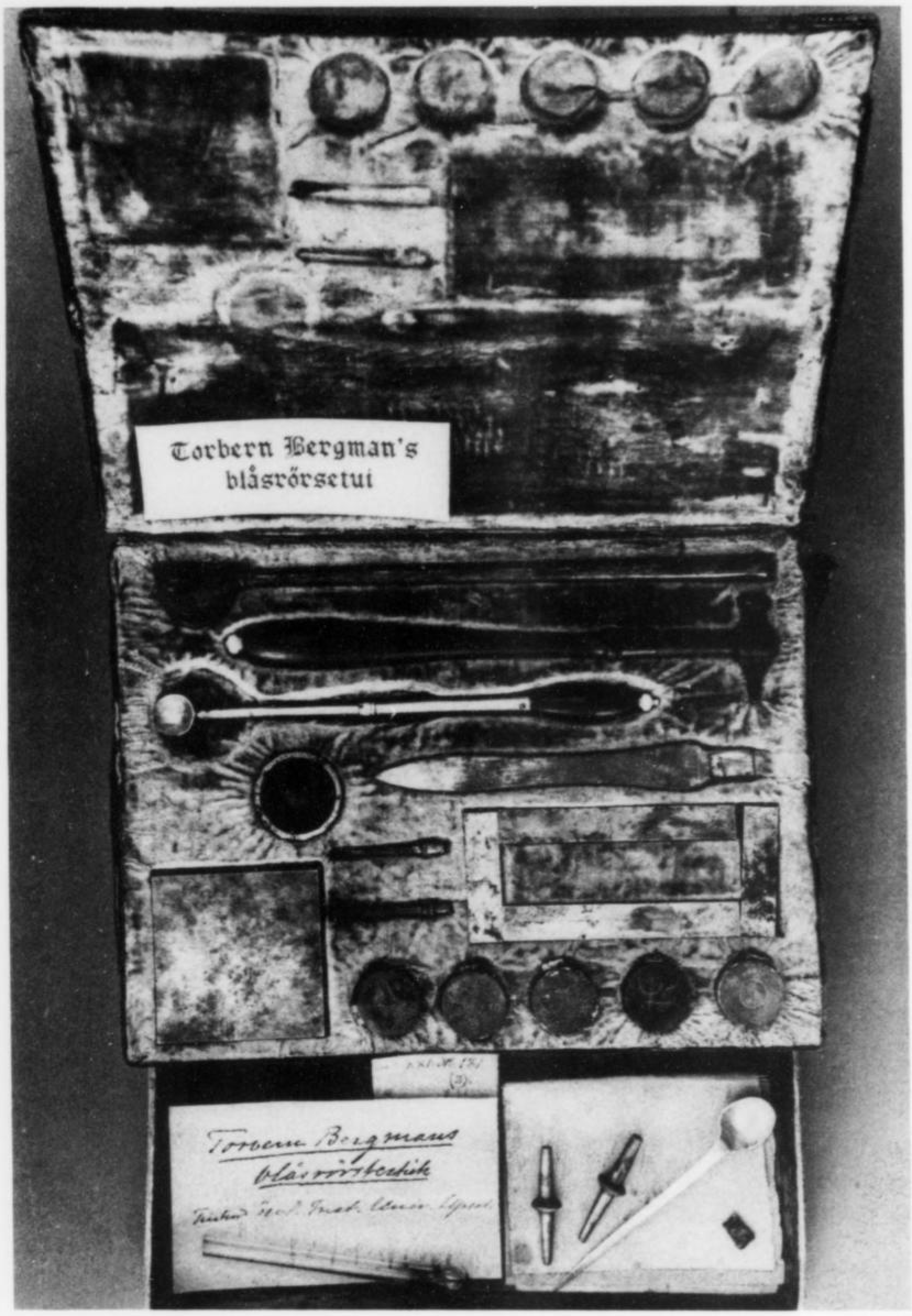


Figure 23. **Bergman's original blowpipe kit. (With permission of Geological Institut, University of Uppsala.)**

neto-electrostatic needles balanced on sharp points.

Berzelius (1821) greatly expanded the blowpipe kit. He invented the oil lamp with collapsible brass stand and rod, and a triangular grid to place dishes upon. Some of his other additions were: a charcoal borer, platinum crucible and wire, and tin cases to store charcoal, glass apparatus and fuel. His reagents were stored in a separate wooden box with nine compartments to contain soda, tin, iron, saltpeter, phosphorous salt, gypsum, fluorite, copper oxide, borax and vitrified borax. Lead, bone ash and cobalt solution were held in separate bottles. Berzelius also used magneto-electrostatic needle balances.

All items were stored in a leather roll (45 by 100 cm) that has survived intact. Berzelius described it as follows:

> On voyages the instruments are all laid in a leather sheath that is made like a surgical bandage. This type of storage is the result of Gahn's many experiments to bring the equipment to its highest level of perfection.

Harkort (1827) favored a wooden case (12 by 27 by 38 cm) in which all his utensils were stored in fitted leather-lined depressions. He introduced the special implements for quantitative analysis. The most important characteristic of his kit is the silver-assay scale and the cupel mold with three hollow hemispheres, and his balance that attached to the lamp holder. Harkort's personal kit is on exhibit at the Freiberg Mining Academy.

The development of blowpipe kits culminated with the construction of the Plattner or Freiberg Apparatus by Plattner and Lingke. This was conceived as a complete and self-sufficient traveling laboratory. However it grew so heavy and unwieldy that Ross (1889) complained:

> The Freiberg apparatus, in the profuse manner by which every one of the too-numerous articles is designed exclusively for its own separate use, however trifling, and for no other, forming at last a bulky box which with its case is almost a porter's load in itself.

The entire apparatus is contained in a sturdy leather case with four compartments, three for individual boxes and one for the collapsible glass case of the field balance. All tools, utensils, fuels, sample supports and the analytical balance are accommodated in one wooden box (22 by 30 by 17 cm). The second one (22 by 30 by 10 cm) contains all fluid and dry reagents as well as glass vessels. The third box (22 by 9 by 10 cm) is reserved for the presses and molds for making charcoal and clay crucibles etc. There are various models of this Freiberg Apparatus, assembled according to the needs of the user. Most of the surviving kits have been cannibalized to some extent during the past hundred years; loupes, scissors, pocket-knives and various other tools were removed and never put back into place. Complete Freiberg kits are consequently extremely rare.

Instrument Makers

Blowpipes are relatively simple and cheap to manufacture. Because of this they were made and sold by many instrument makers. The blowpipe kits are often either unsigned or signed only on some of the items, such as the silver-assay scale, the stand of the lamp holder or on a contact goniometer that might be included in a kit. Companies that traditionally dealt with mining, smelting and surveying instruments also offered blowpipe kits in their catalogs. It is therefore not surprising that the two most important makers of blowpipe kits, Lingke in Freiberg Saxony and Letcher in Truro, Cornwall, were both located close to mining centers.

Germany

In the German states, Johann Heinrich Kopp in his *Grundriss der chemischen Analyse mineralischer Körper* (1805) advertised a pocket laboratory of the "Hanau Mineral Exchange Company." This was accompanied by the instructions of Leonhard, and was sold at a price of 11 Guilders Palatinate or 6 Thalers Saxonian.

In 1835 the Kassel, Hesse Company which Friedrich Wilhelm Breithaupt (1780–1853) founded in 1762, listed a "complete blowpipe apparatus as designed by Berzelius in a leather rollup" for 40 Thalers and "the same in a mahagony table" for 60 Thalers. In later catalogs of the company (which is still in business today) there are no more listings for blowpipe since surveying instruments became the only line of business.

Apparently the blowpipe kit proposed by Berzelius was the standard model around 1830, because the 1829 catalog of the Berlin instrument makers Carl Philipp Heinrich Pistor (1778–1847) and Friedrich Wilhelm Schieck (1790–1870) also listed the leather roll-up for 50 Guilders and the mahogany table set for 70 Guilders.

Under the guidance of J. F. L. Hausmann the Göttingen University mechanic Friedrich Apel (?–1851) manufactured blowpipes, platinum crucibles, mineralogical instruments and goniometers. It was common at the beginning of the 19th century that university mechanics and professors closely cooperated in designing and manufacturing physical apparatus. The historical blowpipe kit of Harkort is preserved in Freiberg. Harkort commented about its maker in 1827:

> Mr. Lingke will supply, for about 25 Thalers, the complete previously mentioned apparatus in a neat box which is furnished with all useful tools and additional compartments for extra reagents. As far as the silver assay scale is concerned, for the present time I will have to manufacture it myself.

On the 2nd of September, 1771, Gottlieb Friedrich Schubert, through an Elector's Decree, received the title of "Berg Mechanikus" at Freiberg and thereby the right to manufacture mining and smelting instruments. Schubert's workshop was assumed by Johann Gotthelf Studer (1763–1832) in 1791. In 1823 Wilhelm Friedrich Lingke (1784–1867) assumed ownership, having began his apprenticeship under Studer in 1809. His son, August Friedrich Lingke (1811–1875), became an assistant after 1840 and manager in 1859. In 1869 Ernst Schramm became a partner, and in 1873 August Friedrich Lingke sold his workshop to Max Hildebrand (1839–1910), who had joined the firm in 1870.

The company was renamed August Lingke & Company, with the addition of Hildebrand & Schramm after 1876. Max Hildebrand bought out Schramm in 1889 and became the sole owner. The firm of Hildebrand (formerly August Lingke & Company) manufactured mostly mining theodolites and other surveying instruments. After the death of Max Hildebrand, his son, Walter Hildebrand, took control of the company in 1912. Following the first World War the company merged with the firms Gebrüder Wichman, Berlin and R. Reiss, Bad Liebenwerda. After being partially dismantled for Soviet reparation, the company was nationalized and called "Volkseigener Betrieb Freiberger Präzisionsmechanik," which will probably be privatized in the near future. Unfortunately all company records have been lost, so that the close cooperation of Harkort, Plattner and Lingke in the development of the "Freiberg Apparatus" cannot be substantiated. Lingke dominated the market for variously sized blowpipe kits from about 1840 to 1880. "Plattner Cabinets," undoubtedly manufactured by Lingke, were sold by companies such as J. Griffin & Son, London, for 24 pounds in 1866. At the beginning of the 20th century the company of Max Kohl, Chemnitz, still sold the "Large blowpipe assay apparatus after Plattner" for 450 marks; this was undoubtedly made by Hildebrand. From at least 1860 to 1870 the two Freiberg mechanics C. Osterland and E. Neumann dealt with the manufacture of blowpipe utensils. No records exist about these two. Since their tools and chemical bottles closely resemble those of Lingke it is very probable that these were made by other Freiberg firms and assembled into kits by Lingke, Osterland and Neumann.

Other German manufacturers of blowpipe implements at the end of the 19th century were the companies of R. Fuess, Berlin-Steglitz; Dieskau & Company, Berlin-Charlottenburg (which sold a blowpipe kit after Hirschwald in a leather case for 28 marks in 1891); Gottlieb Kern & Sohn, Onstmettingen (with individual blowpipe ranging from 1 to 3.6 marks and "assay balances after Plattner in a polished wooden case" for 37.70 marks as well as one in a glass protecting case for 107 marks); W. L. Rohrbeck, Berlin; Richard Müller-Uri, Braunschweig; and F. A. Kühnlenz of Frauenwald, Thuringia.

Great Britain

In England the pocket laboratory of Cronstedt/Engeström was available in the "General Office of Business, Arts & Trade" and later at the shop of William Brown, a book dealer (Smeaton, 1966). In the 1804 London catalog of the Jones brothers, William (1763–1831) and Samuel (1784–1834), the pocket laboratory inspired by Magellan was listed at 2 pounds 12 shillings 6 pence. Friederich Christian Accum (1769–1828) of Soho-London also sold blowpipes, as attested by their inclusion in his letterhead (1805). In 1827 the mineralogical pocket compendium cost 2 pounds 10 shillings from Francis West (?–1846) and William Cary (1759–1825). A "mineralogical traveling chest, containing everything for analyzing mineral substances" was offered for 4 pounds 14 shillings 6 pence. In J. J. Griffin's catalog various blowpipe utensils were described in detail on 32 pages, including a Black type blowpipe costing 8 pence.

In 1878 the company of John Teague Letcher (1851–?), in partnership with his brother Thomas Henry Letcher (1836–?), was founded in Truro, Cornwall, and was later renamed Letcher & Sons, Turnpike, Holborn, London. At the turn of the century the company made relatively simple blowpipe kits that were widely distributed because of their low price (one Guinea). These are sometimes still available in specialty shops. The least expensive version (1 Guinea) contained in a stained box, limited itself to bare essentials. The second kit (1 pound 10 shillings 6 pence) contained extra apparatus in a stained mahogany box. The most expensive model (2 pounds 2 shillings 6 pence), called "Best Blowpipe Set," also had a drawer with 40 crushed mineral samples for reference. Letcher designed a blowpipe set similar to the "Plattner Apparatus" in that a leather case contained a wooden box in which all implements for quantitative analysis, with an assay scale and a comprehensive selection of reagents, were housed. The "Society for the Encouragement of Arts, Manufacturer and Commerce" awarded a silver medal to the Letcher company. E. T. Newton

Figure 24. **Trays of blowpipe utensils in the Freiberg Apparatus made by Lingke, Freiberg, ca. 1870.**

Figure 25. **"Best Blowpipe Set" by T. H. Letcher, Cornwall, ca. 1880.**

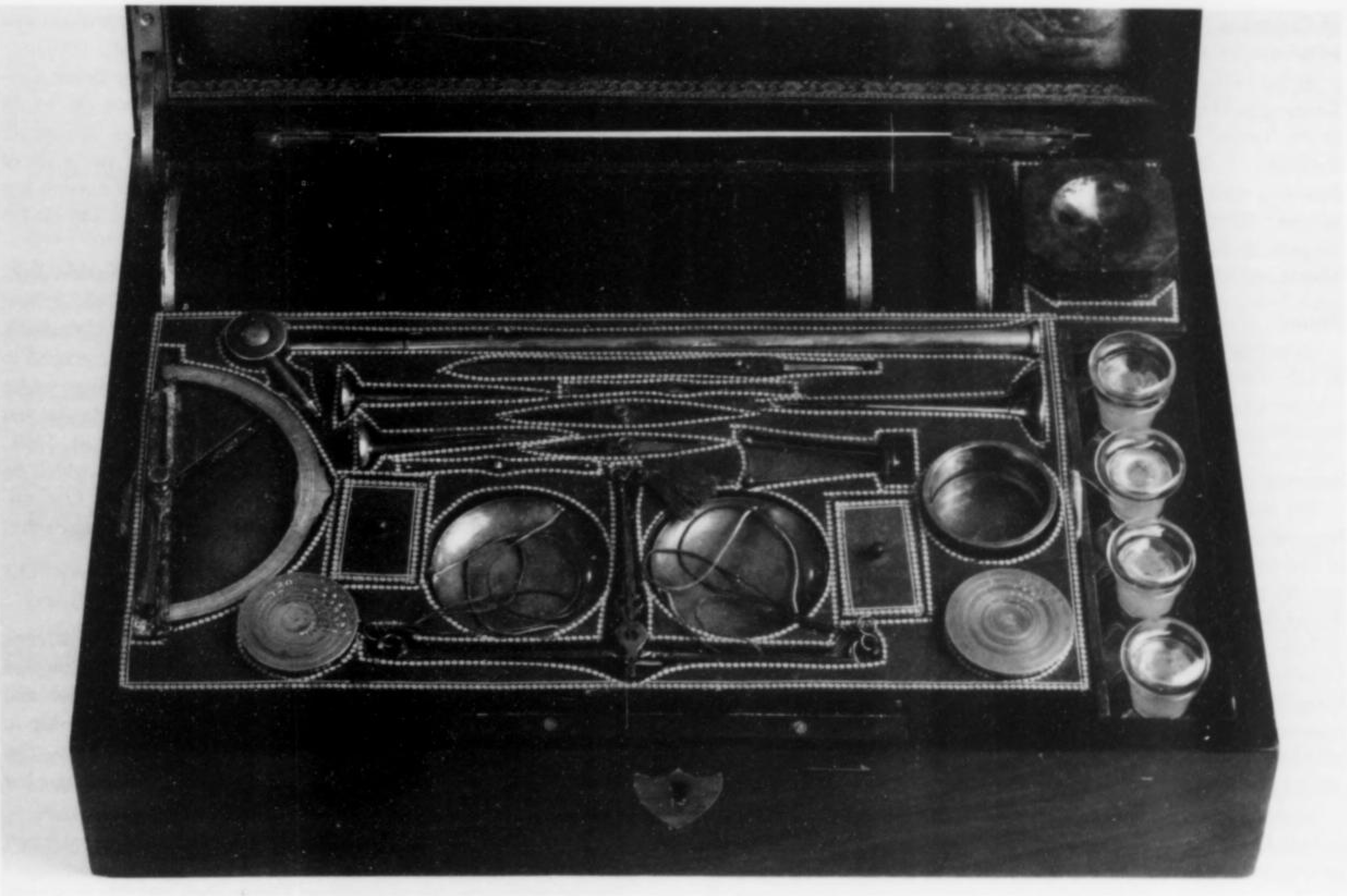
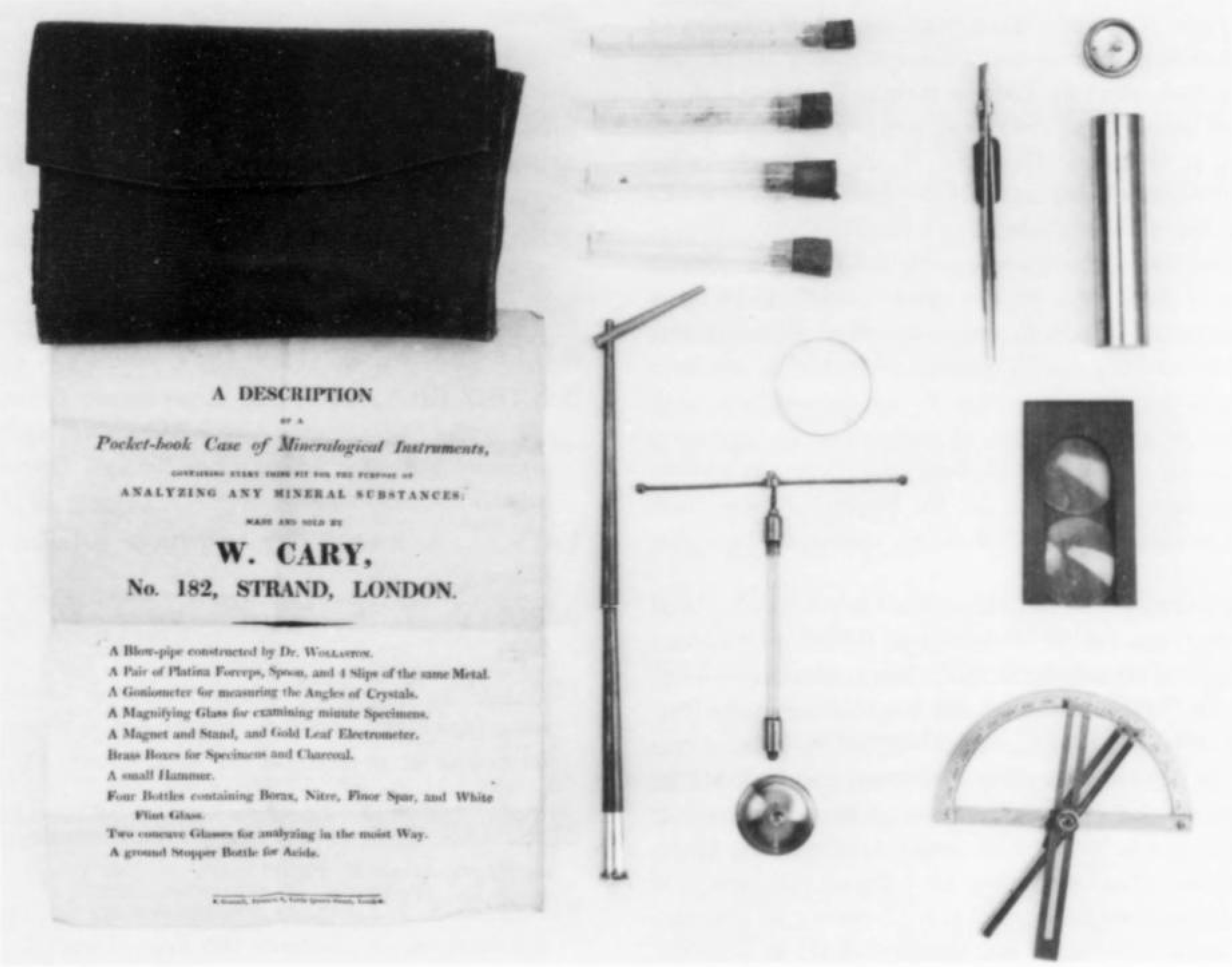


Figure 26. **Early French blowpipe kit by the Pixii company, Paris, ca. 1830; it includes a Voigt model blowpipe, contact goniometer, and Nicholson hydrometer in a tin case.**



A DESCRIPTION

OF A

Pocket-book Case of Mineralogical Instruments,

CONTAINING EVERY THING FIT FOR THE PURPOSE OF

ANALYZING ANY MINERAL SUBSTANCES;

MADE AND SOLD BY

W. CARY,

No. 182, STRAND, LONDON.

A Blow-pipe constructed by Dr. Wollaston.
A Pair of Platina Forceps, Spoon, and 4 Slips of the same Metal.
A Goniometer for measuring the Angles of Crystals.
A Magnifying Glass for examining minute Specimens.
A Magnet and Stand, and Gold Leaf Electrometer.
Brass Boxes for Specimens and Charcoal.
A small Hammer.
Four Bottles containing Borax, Nitre, Fluor Spar, and White Flint Glass.
Two concave Glasses for analyzing in the moist Way.
A ground Stopper Bottle for Acids.

Figure 27. **Pocket mineralogical compendium made by Cary, London, circa 1827; Wollaston type blowpipe.**

of Camborne, Cornwall, manufactured a similar blowpipe kit but of better quality and workmanship.

At the 1876 "World Exhibit of Scientific Instruments" in the South Kensington Museum (predecessor of the present Science Museum next to the Natural History Museum in London) blowpipe kits from the companies J. R. Gregory, James How & Company, and Thomas J. Downing were represented. Other British makers of blowpipe utensils included George Knight & Sons (1851), Townson & Mercer (1894), Negretti & Zambra (1884), L. P. Casella (1871), and Simpson & Maude, all in London.

France

Literature studies and surviving instruments indicate the existence of only a few French instrument makers of blowpipes, such as: Pixii, Vincent Chevalier, and A. Billault, all of Paris. Without doubt many other French manufacturers made blowpipe utensils!

America

The utilization of blowpipe analysis in the United States seems to have persisted long after its decline in Europe. This is probably because of the extensive exploration of the Western states for ore deposits, and the many prospectors who required ore analyses on the frontier during the years 1860–1920. Yale Professor George J. Brush's *Manual of Determinative Mineralogy and Blowpipe Analysis* first appeared in 1874 and became widely used in colleges, going through 15 editions from 1874–1899. Brush and his co-worker, Prof. S. W. Johnson, had been students of von Kobell in Munich in 1853–1854, under whom they had learned blowpiping technique according to the methods of Berzelius and Plattner.

Blowpiping was still being taught at the Colorado School of Mines and the University of Arizona, among many other institutions, in the early years of this century. Blowpipe kits were available through mine supply companies and dealers in assayers' and chemists' equipment as recently as the 1940's.

Some American dealers were probably serving only as distributors of European-made kits. It is unlikely that firms such as J. W. Queens and Company of New York and Philadelphia, Joseph Wightman of Boston, and the prominent mineral dealer George L. English of New York manufactured their own kits. Dealers such as Theodore Kalb of St. Louis advertised proudly that their blowpiping apparatus was imported from Freiberg, Germany. However, H. B. Cornwall, in his 1879 translation of Plattner's *Manual of Blowpipe Analysis*, specifically mentions George Wale & Company of Hoboken, New Jersey, as a manufacturer of kits. Catalogs issued by the Eimer & Amend chemical company of New York list blowpipes manufactured in its own factories. Fletcher (1907) gives a price list of all blowpipe kits offered by the Henry Heil Chemical Company of St. Louis, and John Taylor & Company of San Francisco. Hall & Harbeson of New York advertised apparatus of every description made to order, including Lingke's nickel-plated blowpipes and Plattner's and Berzelius's blowpipe apparatus, separately or in sets. H. M. Raynor of New York fabricated platinum crucibles, spatulas, tweezers, spoons and blowpipe jets.

Among the most common American blowpipe kits produced around the turn of the century was that of G. Montague Butler, an Assistant Professor of Geology and Mineralogy at the Colorado School of Mines, and later Dean of the College of Mines and Engineering at the University of Arizona in Tucson. His kit (measuring 30 by 16 by 7 cm) was sold through the Denver Fire Clay Company, and included an explanatory booklet entitled *Pocket Handbook of Blowpipe Analysis* (1910). The booklet was to be used in conjunction with the kit by anyone with a common-school education. He believed that most field kits were too complicated and bulky, and in consequence he designed his own to be as simple (36 items) and straightforward as possible. Among the efficient tools included was a combination charcoal borer, magnet and chisel. The Denver Fire Clay Company also sold three different collections of bottled mineral samples for comparison and use in learning to perform the analyses (Vendl and Vendl, 1991).

Another American blowpipe kit was produced by the Braun Corporation in Los Angeles. It came in a sort of tackle box (41 by 20 by 15 cm) with cantilevered drawers and internal trays holding 47 items including a Plattner's blowpipe, analytical tools and a set of chemicals (priced in 1940 at $35). Also available was a mineral test set of 50 identified mineral samples in screw-cap vials for $40 (Steinberg, 1993).

The use of the blowpipe proved a boon to Rocky Mountain prospectors. A good example that might be cited is that of Winfield Scott Stratton, who had unsuccessfully prospected nearly all of Colorado's principal silver and gold districts. Deciding at last that he needed to learn more about mineralogy, he enrolled at Colorado College under Professor Henry Lamb. He bought a copy of Cornwall's *Manual* and learned to use the blowpipe. The training paid off on July 4, 1891, when Stratton filed a claim in the Cripple Creek district which he eventually sold for $10 million, becoming Cripple Creek's first millionaire. He was made famous in 1937 by Frank Waters' biography, *Midas of the Rockies*.

CONCLUSION

The contribution of blowpipe analysis to the growth of knowledge in chemistry and mineralogy was immense. The surviving blowpipe kits are witness to an important part of our scientific tradition and culture. Instrument makers showed a high degree of workmanship in the blowpipes they made, paired with a nice sense of aesthetics. The author welcomes any information that would assist in compiling a list of all historical blowpipe apparatus still in existence.

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NEW MINERAL OCCURRENCES FROM THE LAURIUM MINES

GREECE

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The Laurium district today constitutes a natural museum where more than 265 primary, secondary and rock-forming minerals have been found, including several new to science. Because of the variety and beauty of Laurium minerals, many mineralogists and collectors have become interested in the area, and new discoveries continue to be made.

INTRODUCTION

The Laurium mines are situated on the Attica Peninsula of Greece, on the coast of the Aegean Sea. The deposits were first worked by the Myceneans and later (ca. 600 B.C.) by the Athenians for lead and silver. Abandoned around 100 A.D., the mines were not reopened until the early to mid-1800's. Thousands of shafts, mostly unnamed, exist in the area, but the Plaka mine and the Kamareza mine were of particular importance.

Many interesting minerals have been discovered underground, and on the dumps, and many more occur as post-mining crystallizations in gas pockets in ancient smelter slag. Micromineral collectors have found Laurium minerals to be particularly appealing.

Early descriptions of Laurium include those of Ardaillon (1897), Daviot (1899), and Putzer (1948). The first systematic effort to record the minerals occurring at Laurium was that of Marinos and Petrascheck (1956), followed 20 years later by a review article in the *Mineralogical Record* (Kohlberger, 1976) and an update on new discoveries by Jaxel and Gelaude (1986).

Our own effort has involved a systematic survey of the Laurium minerals through X-ray diffraction analysis of crystals carefully isolated under a stereoscopic microscope. Thirteen minerals, described here, have thus far been identified which are new to the Laurium list. Some have been found in slag specimens, and others were brought to our attention by P. Gelaude, C. Rewitzer, H. Hanke and V. Perdikatsis (personal communications).

MINERALS

Boulangerite $Pb_5Sb_4S_{11}$

Boulangerite has been identified as fibrous aggregates and acicular crystals from the Kamareza mine, associated with sphalerite, arsenopyrite, quartz and pyrite. The lead-gray crystals are opaque and metallic.

Cryptomelane $K(Mn^{4+},Mn^{2+})_8O_{16}$

Massive to radial aggregates of black, metallic cryptomelane have been found at the 3-km point along the old Laurium-Kamareza road, associated with annabergite and magnesian calcite.

Devilline $CaCu_4^{2+}(SO_4)_2(OH)_6 \cdot 3H_2O$

Transparent, vitreous, bluish green encrustations of devilline associated with serpierite, schulenbergite and namuwite occur at the Kamareza mine.

Halite $NaCl$

Colorless to white halite encrustations have been found at the Christiana mine.

Hollandite $Ba(Mn^{4+},Mn^{2+})_8O_{16}$

Short, silver-gray prisms of hollandite, the barium analog of cryptomelane, have been found associated with calcite at the 3-km point along the old Laurium-Kamareza road.

Linarite $PbCu^{2+}(SO_4)(OH)_2$

Elongated, thin bladed crystals of blue linarite have been found at

Kamareza, associated with cuprite, malachite and azurite.

Litharge PbO

Red, oily-looking litharge has been found in the Megala Pefka and Soureza areas, usually as foliated encrustations in oxidized lead ore.

Namuwite $(Zu,Cu^{2+})_4(SO_4)(OH)_6 \cdot 4H_2O$

Radial aggregates of pearly, pale bluish green namuwite occur with gypsum, serpierite, ktenasite and calcite at Kamareza.

Plattnerite PbO_2

Black, prismatic plattnerite crystals on limonite have been identified at Kamareza.

Römerite $Fe^{2+}Fe^{3+}_2(SO_4)_4 \cdot 14H_2O$

Scattered, pale orange crystals of vitreous, translucent römerite have been found at the Plaka mine, associated with halotrichite, chalcanthite and voltaite.

Saponite $(Ca,Na)_{0.3}(Mg,Fe^{2+})_3(Si,Al)_4O_{10}(OH)_2 \cdot 4H_2O$

Massive, white to yellowish saponite having a greasy luster occurs at Kamareza.

Tyrolite $CaCu^{2+}_5(AsO_4)_2(CO_3)(OH)_4 \cdot 6H_2O$

Pale blue to greenish blue encrustations of vitreous tyrolite have been found at Kamareza, associated with malachite and azurite.

Voltaite $K_2Fe^{2+}_5Fe^{3+}_4(SO_4)_{12} \cdot 18H_2O$

Earthy, black aggregates of voltaite with halotrichite, chalcanthite, tamarugite and römerite have been identified from the Plaka mine.

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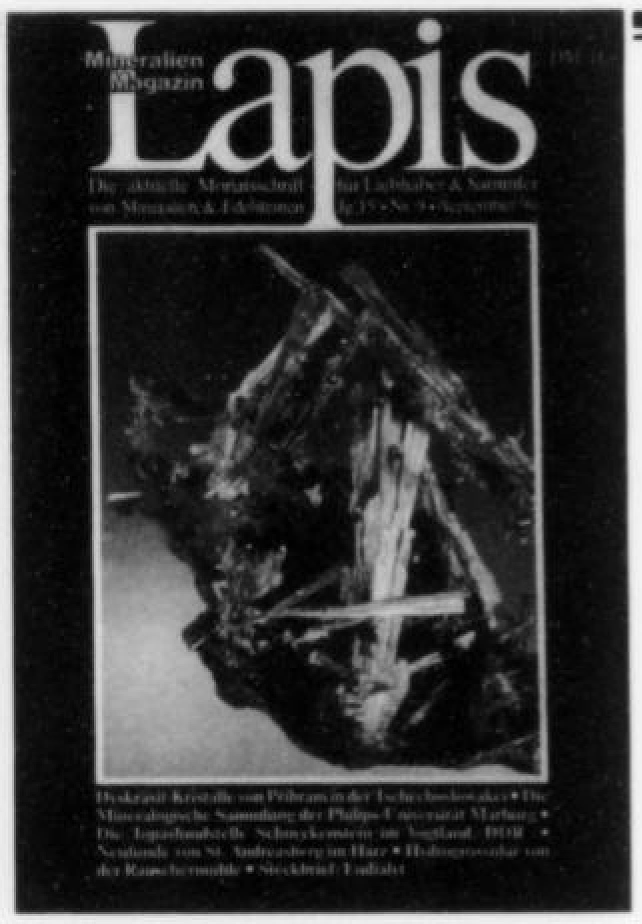

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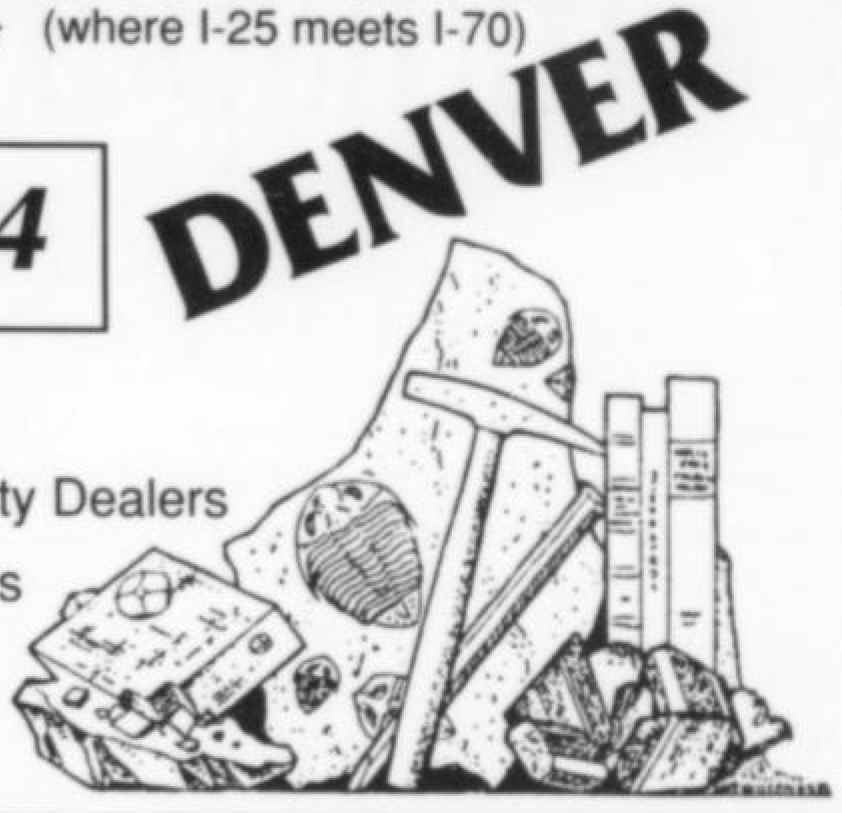

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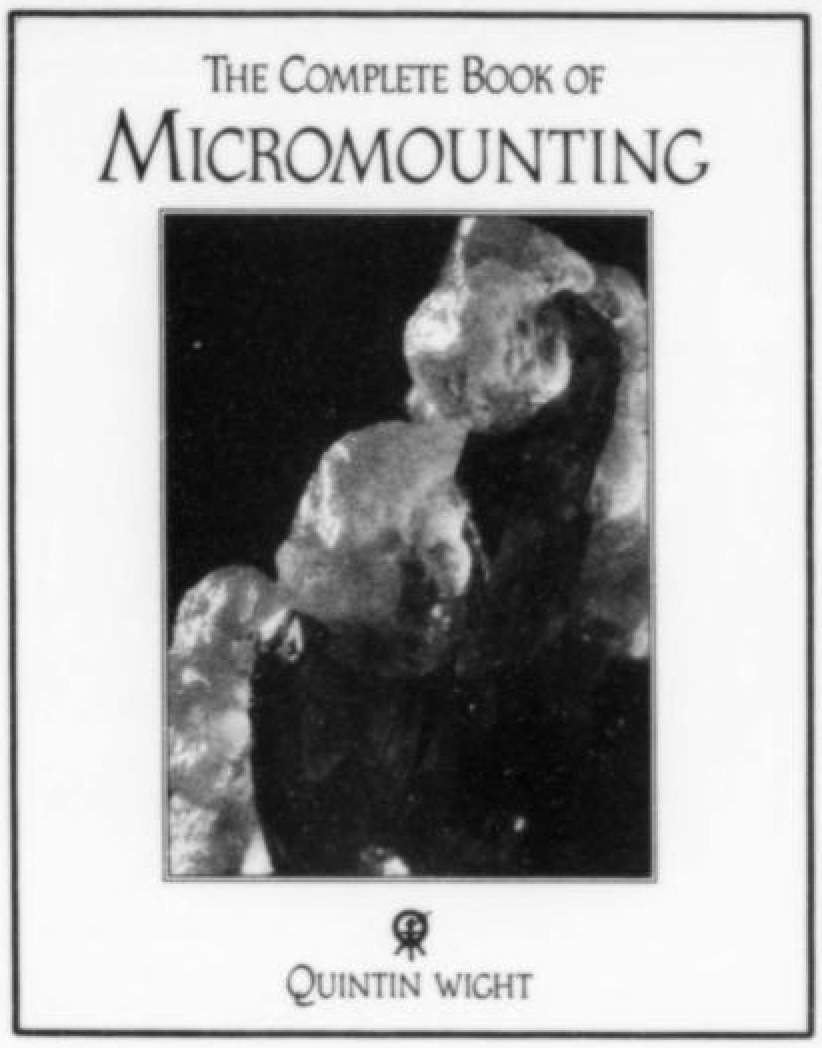

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The 132 North open-pit nickel mine at Widgiemooltha in Western Australia has produced the greatest variety of secondary nickel minerals found anywhere in the world to date, some of them being the best of their species. It is the type locality for widgiemoolthalite and hosts the second known occurrence of kambaldaite and nullaginite.

INTRODUCTION

The 132 North deposit is one of a number of small komatiite (ultramafic)-hosted nickel sulfide deposits in the Widgiemooltha district (McQueen, 1981; Marston *et al.*, 1981). It is located 5 km north-northwest of the small community of Widgiemooltha and about 80 km south of the city of Kalgoorlie-Boulder (Fig. 1). The deposit gossan was discovered in 1968 by International Nickel Australia Limited during extensive geological mapping, gossan search and geochemical sampling of the Widgiemooltha district. The deposit was purchased by Western Mining Corporation in 1981, and subsequent percussion drilling in 1989 located a small sulfide nickel orebody (approximately 900 metric tons of contained Ni) that was economical to mine.

Western Mining Corporation (WMC) commenced a small opencut on the deposit in 1990. During excavation, a series of five horizontal channel samples was collected (by JFMC) across the ore zone at 10-meter-depth intervals from the surface down to a depth of 40 meters. Samples were also collected from drill core and percussion holes. Following completion of the opencut, one of us (BJG) was granted permission by WMC to collect specimens from the excavated material. Over a thousand specimens were collected, of which over a hundred have been subjected to detailed examination in the CSIRO[2] laboratories.

The specimens required careful examination with the aid of a binocular microscope, and small particles of the minerals to be identified were transferred onto adhesive plates for examination under the scanning electron microscope (SEM). Compositional spectra were obtained

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[2] Commonwealth Scientific and Industrial Research Organization.

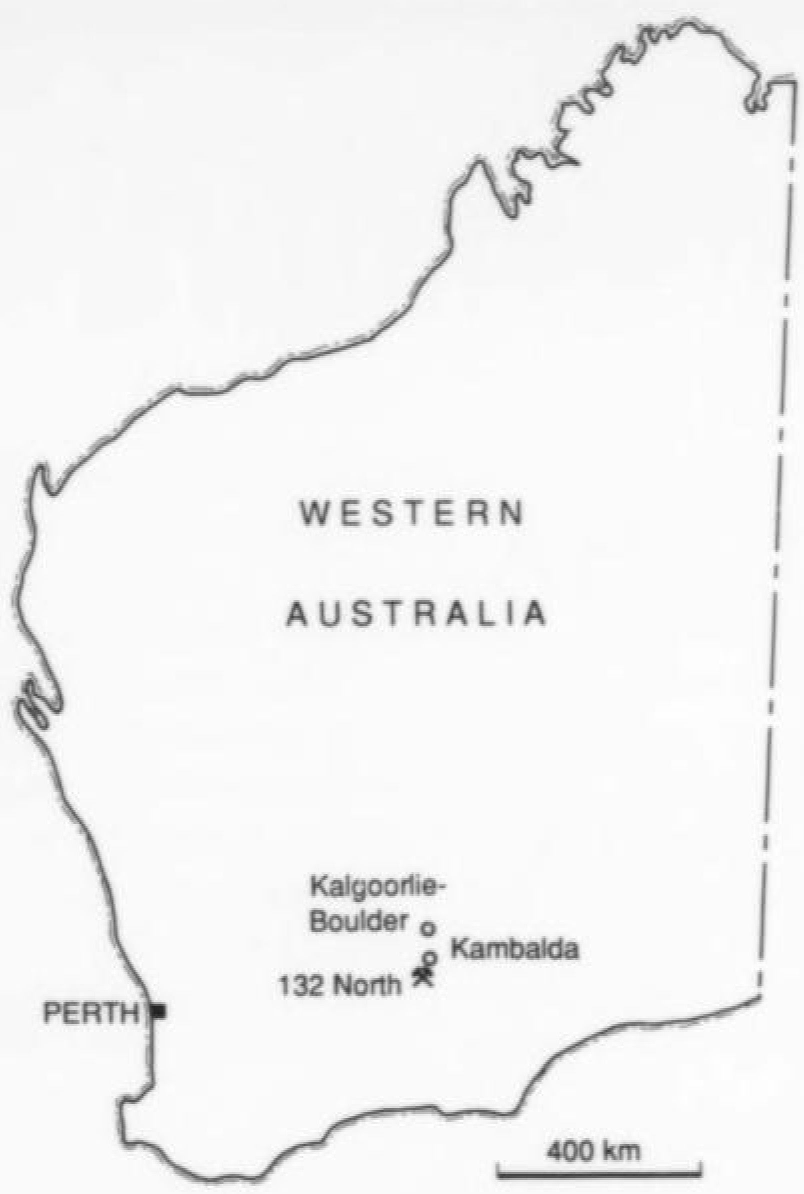

***Figure 1.* Sketch of Western Australia showing location of the 132 North deposit.**

under the SEM by means of energy-dispersive spectrometry (EDS). Initially the particles for which compositional spectra were obtained were subjected to X-ray diffraction (XRD) analysis, which enabled the minerals to be positively identified. Subsequent identifications were based largely on the EDS spectra, supplemented by XRD patterns in cases of doubt.

For ease of reference, the mineral descriptions in this paper are arranged in alphabetical order of mineral name.

GEOLOGY

The 132 North deposit is located on a relatively high relief-etch surface that is part of a ridge extending 20 km north-northwest from Widgiemooltha (Finkl, 1979; Clarke, 1991). The surface expression of the deposit is characterized by rubbley outcrops of fresh to slightly weathered metabasalt and more strongly weathered ultramafic rock. Weathering of the metabasalt is typically best developed along joint planes where it persists to depths of up to 30 meters. The relatively thin weathered profile is interpreted as the residue of a much thicker profile, of Tertiary age, that has been largely removed by erosion (Marston *et al.*, 1981; Clarke, 1991).

The 132 North deposit is within the Archean Greenstones of the Kalgoorlie Terrane dated at 2,700 Ma (Swager *et al.*, 1992). The local stratigraphy (Fig. 2) consists of a lowermost tholeiitic basalt unit (pillowed to massive flows)—the Mt. Edwards Basalt Formation—which is in turn disconformably overlain by the Widgiemooltha Komatiite Formation (olivine peridotites to picrites). The 132 North deposit is within the basal ultramafic lava flow of the latter.

Extensive thrust-stacking of the succession (Archibald, 1987) was followed by middle-amphibolite-facies metamorphism and the intrusion of syn-kinematic domal granitoids, such as the Widgiemooltha Monzogranite (Binns *et al.*, 1976; Archibald *et al.*, 1978; McQueen, 1981) during peak metamorphism and cleavage formation at about 2,660 Ma (Hill and Compston, 1986). Ultramafic (picritic) rocks north of the Widgiemooltha Dome (Fig. 2) typically comprise a peak metamorphic assemblage of antigorite-lizardite with or without relict olivine (McQueen, 1981), whereas subsequent retrograde CO_2 alteration in the 132 North mine area has largely converted these assemblages to a tremolite-chlorite-dolomite (± talc-magnesite) assemblage. The peak metamorphic assemblage in the Mt. Edwards Basalt is typically actinolite-albite-quartz-epidote-biotite, and this has been altered during retrograde CO_2 alteration to an actinolite-quartz-dolomite-chlorite (± pyrrhotite) assemblage.

The structure of the 132 North deposit is dominated by a small north-plunging parasitic isoclinal fold which lies on the steeply dipping western limb of the 132 Anticline, immediately north of the Widgiemooltha Dome (Fig. 2). The synclinal core of this isoclinal fold (Fig. 3) is marked by a long (>200 meters), narrow (5–20 meters) wedge of the Widgiemooltha Komatiite. Primary nickel sulfide mineralization occurs as a continuous layer which has been folded about the syncline (Fig. 3), with some structural thickening of the ore in the keel of the syncline.

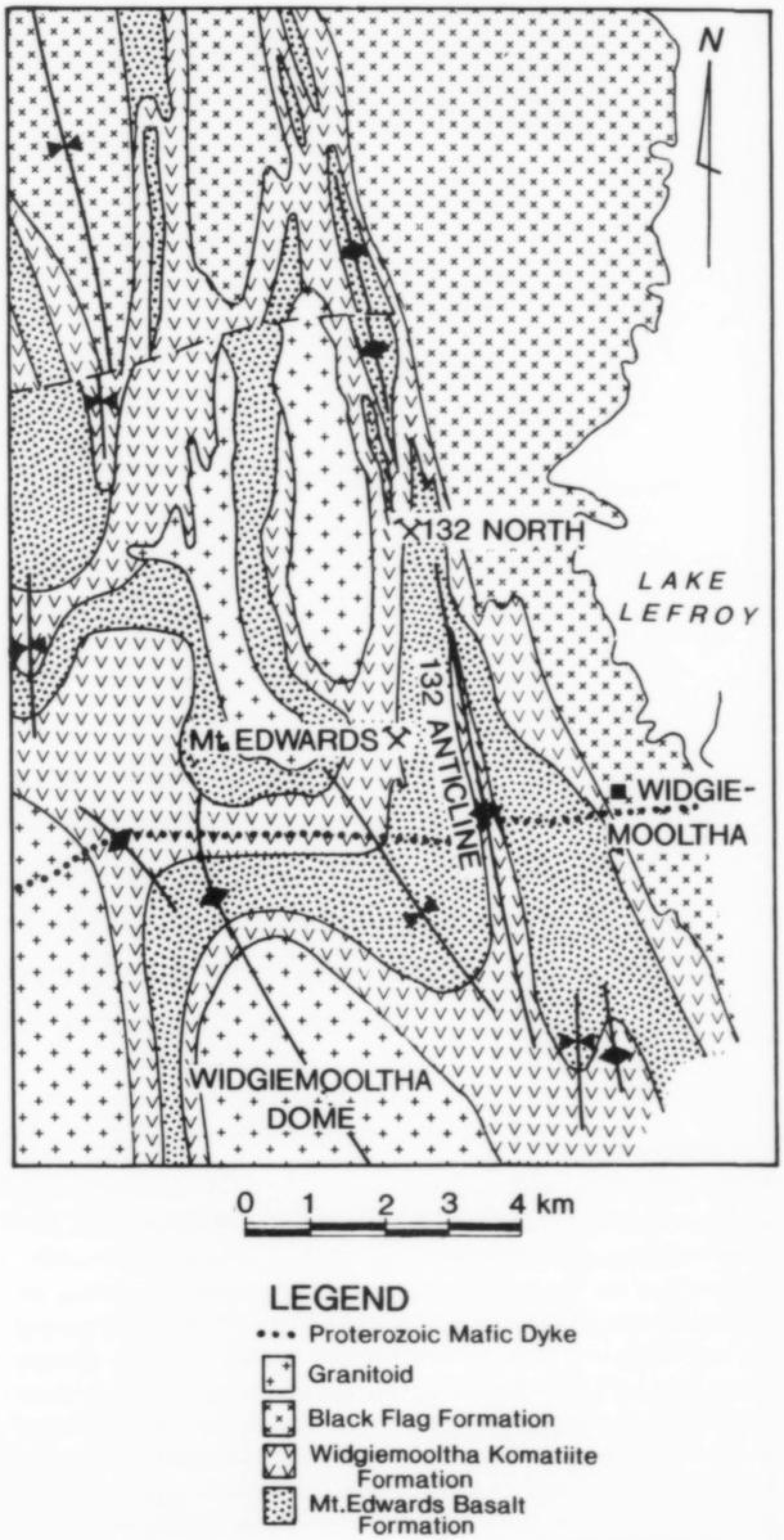

***Figure 2.* Geology of the 132 North-Widgiemooltha area. Adapted from Western Mining Corporation maps.**

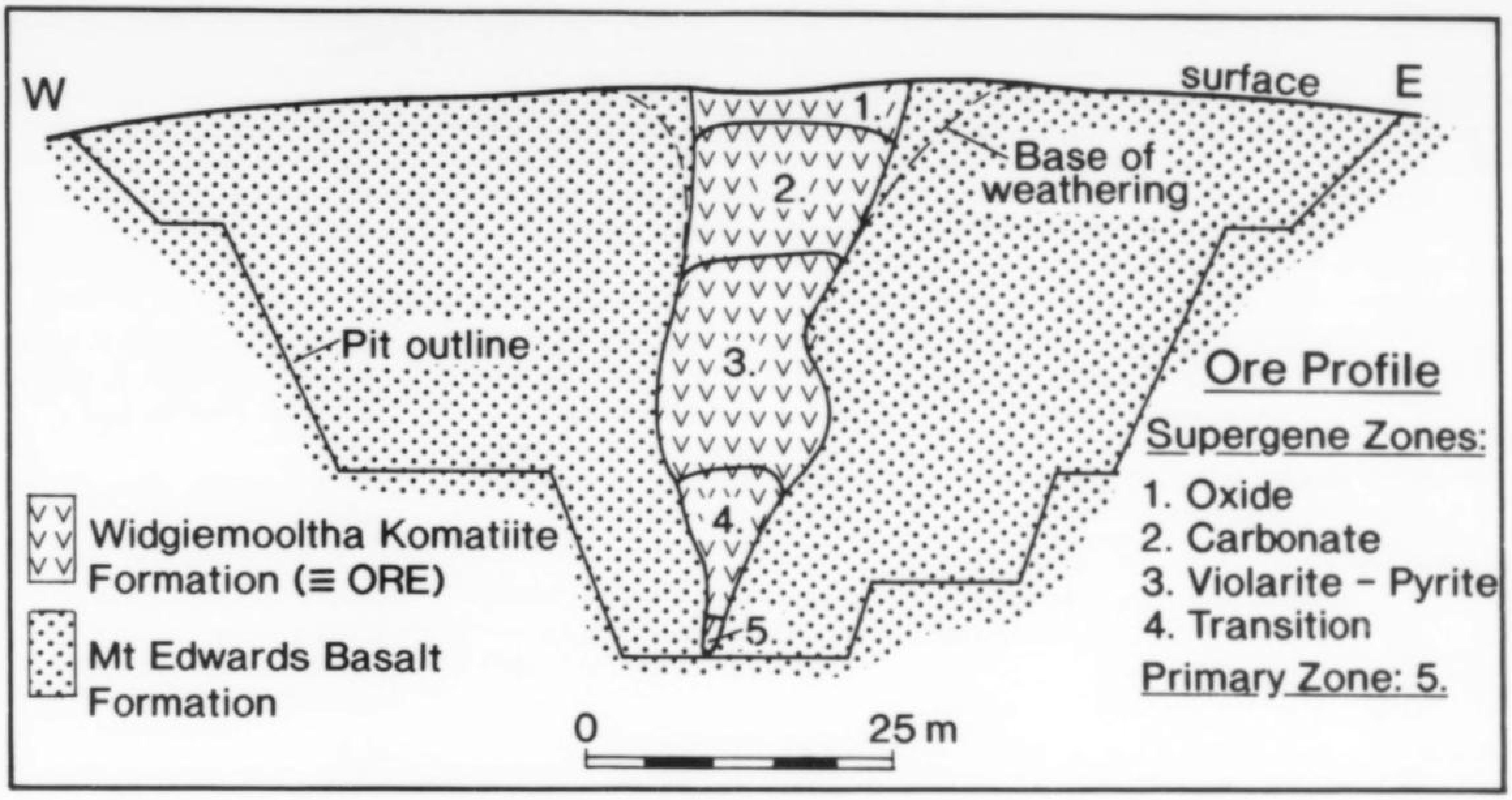

Figure 3. **Vertical cross-section, looking north, of the mining excavation, showing the geology and distribution of the supergene alteration zones.**

NICKEL MINERALIZATION

As shown in the cross-section of the opencut (Fig. 3), the supergene profile of the 132 North nickel mineralization can be divided into five zones, four of which are common to many of the profiles of nickel sulfide deposits in the Kambalda area (Woodall and Travis, 1969; Thornber, 1972; Nickel *et al.*, 1974; Thornber, 1975a, b; Thornber and Nickel, 1976). The fifth, a very distinct and thick carbonate zone, has also been recognized; the upper portion of this zone is the main host for the abundant variety of nickel-bearing and copper-bearing minerals described in this paper. Contacts between each of the five alteration zones is typically gradational and is strongly influenced locally by the presence of fractures, joints and veins. The principal minerals comprising the five zones are listed in Table 1. Ore textures in the primary, transition, violarite-pyrite and oxide zones are similar to those described by Nickel *et al.* (1974).

Primary Zone

The primary nickel sulfide mineralization consists of a typical Kambalda-style profile (Cowden and Roberts, 1990): a layer of massive sulfides (>80% sulfides), 0.1 to 1 meter thick, at the base of the Widgiemooltha Komatiite, overlain by a 0.3–8 meter thick "matrix" sulfide layer (40–80% sulfides), and an uppermost 0.1–2 meter thick layer of heavily disseminated sulfides (5–40% sulfides). The primary zone is usually restricted to deeper than 45 meters below surface (Fig. 3). The ores are largely of matrix type to heavily disseminated sulfides, including all of the area shown as Widgiemooltha Komatiite in Figure 3, and consist of sulfides (10–70%) and interstitial bladed to acicular tremolite (20–60%) as well as minor dolomite (5–20%) and chlorite (2–10%). The main primary sulfides in the massive layer are monoclinic pyrrhotite (30–70%), pentlandite (3–40%), and minor pyrite (1–5%) and chalcopyrite (1–5%). Spinel-group phases, such as chromite, occur in minor amounts within all three sulfide layers. Gersdorffite and nickeline occur with dolomite and as vein fillings which cut across the main upright cleavage and sulfide layering.

As shown in Table 1, for a particular depth, supergene alteration is most extreme in the massive ore, less so in the matrix ore, and least of all in the disseminated ore.

Transition Zone

The transition zone occurs between about 30 and 45 meters below the surface (Fig. 3). The lowermost portion of the zone is marked by the appearance of minor amounts (0.5–2%) of smythite and violarite (Table 1) which are typically more abundant in massive sulfides than in the matrix and disseminated sulfides. In the latter, violarite is usually present only around microfractures.

In the upper part of the transition zone, all of the pentlandite in the massive ore has been replaced by violarite (high Ni), and at least 20–40% of the pyrrhotite has been replaced by violarite (low Ni). Relict pentlandite is occasionally present in the disseminated sulfides, even in the upper part of the zone.

Violarite-Pyrite Zone

The violarite-pyrite zone, which accounted for most of the sulfide ore in the opencut, occurs between about 14 and 30 meters below the surface (Fig. 3).

The mineralogy of this zone (Table 1) is characterized by the replacement of all the pyrrhotite by violarite (low Ni) and, to a lesser extent, the replacement of chalcopyrite by covellite or traces of chalcocite. Near the top of the zone there is an increasing amount of marcasite and, near fractures and at the top of the zone, there is significant replacement of violarite and pyrite by microporous goethite. Nickel sulfates sometimes encrust cavities or line microfractures within goethite that has partly replaced violarite. The matrix and disseminated layers contain far less goethite than the massive layer.

Carbonate Zone

The carbonate zone extends from about 3 to 12 meters below the surface. The zone is characterized by the presence of numerous flat-lying to sub-horizontal veins of gaspeite that cut across the altered wallrock (tremolite and goethite) and extend from what was the massive sulfide layer across the matrix layer. In the structurally thickened

Table 1. **Alteration zones in the supergene profile at the 132 North Deposit.**

Zone	*Massive*	*Matrix*	*Disseminated*
Oxide	**goethite**, quartz, ± azurite, gaspeite, hematite, magnesite	**clays**, goethite, quartz, gypsum, ± gaspeite, hematite, magnesite	**clays**, goethite, quartz, gypsum ± magnesite
Carbonate			
Upper	**gaspeite, magnesite**, goethite, various Ni carbonates & sulfates, gypsum, ± Cu carbonates & sulfates	clays, goethite, **gaspeite, magnesite**, gypsum, ± tremolite, various Ni carbonates & sulfates, Cu carbonates & sulfates, pyrolusite	**clays**, goethite, gypsum, ± gaspeite, magnesite, tremolite, Ni carbonates & sulfates, Cu carbonates & sulfates
Lower	**gaspeite**, goethite, gypsum	**tremolite**, goethite, clays, gypsum, gaspeite ± magnesite	**tremolite**, goethite, clays, gypsum ± gaspeite, magnesite
Violarite-Pyrite	**violarite**, pyrite, marcasite, goethite, covellite ± chalcocite, gersdorffite, siderite, retgersite	**tremolite**, siderite, violarite, pyrite, dolomite, goethite, marcasite ± covellite, gersdorffite, retgersite	**tremolite**, dolomite, chlorite, violarite, pyrite, serpentine ± siderite, chromite, covellite, goethite
Transition			
Upper	**violarite**, pyrite, marcasite, chalcopyrite, ± gersdorffite, nickeline, chromite, siderite	**tremolite**, dolomite, violarite, pyrite, marcasite, chlorite, siderite, ± chalcopyrite, chromite, gersdorffite, nickeline, pyrrhotite	**tremolite**, dolomite, chlorite, pyrrhotite, violarite, pyrite, ± serpentine, smythite, pentlandite, chalcopyrite, chromite, talc, magnesite
Lower	**pyrrhotite**, pentlandite, chalcopyrite, smythite, ± violarite, pyrite, gersdorffite, nickeline, chromite	**tremolite**, dolomite, pyrrhotite, chlorite, pentlandite, smythite, ± pyrite, violarite, siderite, chalcopyrite, chromite, gersdorffite, nickeline	**tremolite**, dolomite, chlorite, pyrrhotite, pentlandite, ± serpentine, smythite, violarite pyrite, chalcopyrite, chromite, talc, magnesite
Primary	**pyrrhotite**, pentlandite, chalcopyrite, pyrite ± gersdorffite, nickeline, chromite	**tremolite**, dolomite, pyrrhotite, chlorite, pentlandite, ± pyrite, chalcopyrite, chromite, gersdorffite, nickeline	**tremolite**, dolomite, chlorite, pyrrhotite, pentlandite, ± serpentine, chalcopyrite, chromite, talc, magnesite

keel of the syncline gaspeite veins are thick and closely stacked, with gaspeite vein material comprising about 30–50% of the total rock in any vertical section through the zone. Individual gaspeite veins have dimensions of 5 x 5 x 0.05 meters (many are up to 10 x 10 x 1 meters); they are typically massive and either granular or fibrous. There is a progressive decrease in the amount of gaspeite and other carbonate minerals, and their respective nickel contents, from the lower part of the carbonate zone to the upper, and from the carbonate zone to the top of the oxide zone.

The lower part of the carbonate zone is dominated by gaspeite veins, and these are typically devoid of any other phases except gypsum, minor goethite, occasional paratacamite, and a few very minor phases (Table 1). At the bottom of the carbonate zone where it meets the violarite-pyrite zone, gaspeite veins are usually more nickel-rich (>25% Ni) and may extend down into violarite-pyrite ore.

In the upper part of the carbonate zone, gaspeite veins are extensively leached, and often contain numerous vugs and cavities that are lined by thin coatings of a large variety of unusual nickel-bearing and copper-bearing minerals (Table 2). In some cases, the gaspeite veins have been almost completely leached out, leaving isolated pillars, and the unusual phases have been precipitated directly onto the wallrock. The transition between the upper and lower parts of the carbonate zone is marked by a mixed paragenesis of carbonates, sulfates and chlorides precipitated in close proximity.

Table 2. **Minor and rare phases in the carbonate zone.**

Carbonate Zone	*Minor Phases*	*Rare Phases*
Upper	paratacamite, carrboydite, glaukosphaerite, hydrohonessite, retgersite, pyrolusite, huntite, aragonite, calcite, pecoraite ± dolomite	kambaldaite, annabergite, azurite, lavendulan, nepouite, nullaginite, olivenite, otwayite, pharmacosiderite, reevesite, takovite, widgiemoolthalite
Lower	paratacamite, dolomite, huntite	kambaldaite

Weathered metabasalt immediately adjacent to the gaspeite veins in the upper carbonate zone contains only thin (0.1–5 mm) coatings of lavendulan, gypsum and minor azurite along joint planes. The upper carbonate zone also marks the site of the breakdown of the tremolite-rich wallrock to clays, goethite and quartz.

Oxide Zone

The oxide zone (Table 1) consists of a highly silicified gossan containing between 0.3 and 5.3 weight % Ni, and extends from the surface down to about 3 meters. All the iron sulfides and nickel carbonates and sulfates have been replaced by goethite (40–70%) and silica (up to 60%). However, despite the complete replacement, patches of goethite often retain ghost outlines of the typical octahedral pattern of shrinkage fractures of what was violarite after primary pentlandite. Such textures, similar to those described by Nickel *et al.* (1977a) and Roberts and Travis (1986), are important for distinguishing nickel gossans from the non-gossanous ironstone occurring in great abundance in Western Australia.

Minor traces of retgersite, azurite, magnesite and pale green gaspeite have been found along microfractures in some gossan samples. Magnesite occurs as occasional small (5–20 mm) nodules and vein fragments within the strongly weathered ultramafic rock, now largely clays, at the core of the syncline.

SECONDARY NICKEL MINERALS

Annabergite $Ni_3(AsO_4)_2 \cdot 8H_2O$

Annabergite is a relatively rare mineral, occurring in open fractures mainly as clusters of transparent, pale green to bluish green and bright green prismatic crystals up to about 5 mm in length. The clusters are up to 1 cm in diameter. Annabergite also occurs as fine-grained powdery surface coatings.

Carrboydite $(Ni,Al)_8(SO_4)_{1.6}(OH)_{16} \cdot 8.5H_2O$

Carrboydite, first discovered at the Carr Boyd nickel mine in Western Australia (Nickel and Clarke, 1976), is common in the upper part of the carbonate zone at Widgiemooltha. It occurs mainly as thin dustings and coatings on joint surfaces, but thicker coatings, massive veins and fracture fillings up to about 7 mm thick have also been encountered. The latter material probably represents the best specimens of carrboydite found to date. Carrboydite has also been observed as a replacement of magnesite and gaspeite nodules. Carrboydite is generally bluish green in color, with variations toward pale green, yellowish green, and greenish blue. Its luster varies from dull to waxy.

Dolomite (nickeloan) $CaMg(CO_3)_2$

Supergene dolomite occurs within both parts of the carbonate zone, but is more abundant in the lower portion. Transparent, vitreous, pale green crystals and rounded crystal aggregates of nickeloan dolomite, averaging about 1 mm in size, were found in a few specimens. Presumably the Ni partially substitutes for Mg in the dolomite lattice.

***Table 3.* Electron microprobe analysis of gaspeite.**

Anal. no.	1 50469	2 50437	3 50440	4 50446	5 50428	Theoretical $NiCO_3$
NiO	34.9	37.3	45.6	52.8	54.5	62.93
MgO	28.0	15.2	10.1	5.7	3.6	
CaO	1.4	2.6	1.5	nd	nd	
CO_2	35.7	44.9	42.8	41.5	41.9	37.07

Analyst: G. J. Hitchen; CO_2 calculated by difference

Gaspeite $(Ni,Mg,Fe)CO_3$

Gaspeite is very abundant in the carbonate zone, predominating over all the other secondary nickel minerals. Its most spectacular occurrence is in the lower part of the carbonate zone, where it was seen as massive lime-green veins up to 50 cm thick and from 1 to 10 meters in lateral extent. In the upper part of the carbonate zone, most of the gaspeite veins have irregular vuggy openings that are lined by a later generation of gaspeite, both as nodular concretions and as rhombohedral crystals. Gaspeite also commonly occurs as thin coatings, often on a substrate of white magnesite. In a few specimens the dense gaspeite exhibits brown swirls due to iron, which create unusual patterns.

There is a progressive decrease in the nickel content of gaspeite, and an increase in the degree of leaching from the bottom of the carbonate zone to the top. Gaspeite is isomorphous with magnesite, its magnesium analog, and specimens from the deposit show a virtually complete range between the two end members. This compositional range is reflected in the color of the minerals, going from white at the magnesite end of the series to a bright apple green, or even dark emerald-green at the gaspeite end. Some analyses of the more nickel-rich specimens are given in Table 3.

***Table 4.* Electron microprobe analyses of glaukosphaerite and nickeloan nullaginite.**

Anal. no.	52746	52755	52759	52751	52738	Theoretical Ni:Cu = 1:1
NiO	21.4	27.5	32.8	34.6	40.8	34.54
CuO	40.2	38.6	33.1	30.4	24.8	36.78
MgO	3.8	nd	0.2	0.4	0.3	–
SO_3	0.1	1.1	0.4	0.4	0.5	–
$CO_2 + H_2O$	34.5	32.8	33.5	34.2	33.6	28.68

Analyst: G. J. Hitchen; $CO_2 = H_2O$ calculated by difference

Glaukosphaerite $(Cu,Ni)_2CO_3(OH)_2$

Glaukosphaerite, originally discovered at Widgiemooltha (Pryce and Just, 1974), is fairly abundant in the carbonate zone where it occurs mainly as green spherules consisting of radiating fibers. A less common occurrence is as a felted mass of greenish blue fibers in roughly parallel alignment. The glaukosphaerite exhibits a considerable compositional variation in terms of its Ni:Cu ratio, as shown in Table 4. There is an appreciable analytical shortfall, indicated by the excessive $CO_2 + H_2O$ calculated by difference; this may be due to the presence of additional adsorbed water. Compositions with Ni exceeding Cu can be regarded as nickeloan nullaginite (see below), and this appears to be the first recorded example of a partial nullaginite-glaukosphaerite solid-solution series.

Hydrohonessite $Ni_6Fe_2SO_4(OH)_{16} \cdot 7H_2O$

Hydrohonessite, first found in Western Australia (Nickel and Wildman, 1981), is fairly common at the top of the upper carbonate zone, and specimens from this deposit probably represent the best ones found to date. The mineral generally occurs in the carbonate zones as a porous, bright yellow to greenish yellow powder lining cavities and on fracture surfaces. At high magnification under the SEM, the powder can sometimes be resolved into tiny hexagonal platelets or aggregates of spheroidal particles showing a foliated texture. The hydrohonessite also occurs in seams up to 1 cm thick, sometimes intergrown with gypsum, and as a finely porous greenish yellow sponge. One specimen revealed hollow, pale green spherules consisting of a mixture of glaukosphaerite and hydrohonessite.

Kambaldaite $NaNi_4(CO_3)_3(OH)_3 \cdot 3H_2O$

Kambaldaite was originally discovered in material from the Otter Shoot at Kambalda (Nickel and Robinson, 1985), and its occurrence at the 132 North deposit represents the second known locality for this mineral. It occurs mainly in the lower part of the carbonate zone. Kambaldaite was found in a few of the specimens as bright emerald-green crystalline spheres up to 3 mm in diameter, and as clusters of prismatic crystals, up to 1.5 mm in length. Areas as large as 6 to 8 square cm are covered by these crystals, in clusters up to about 1 cm


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Figure 4. Unnamed fibrous hydrous nickel carbonate; the fibers are about 6 mm long.

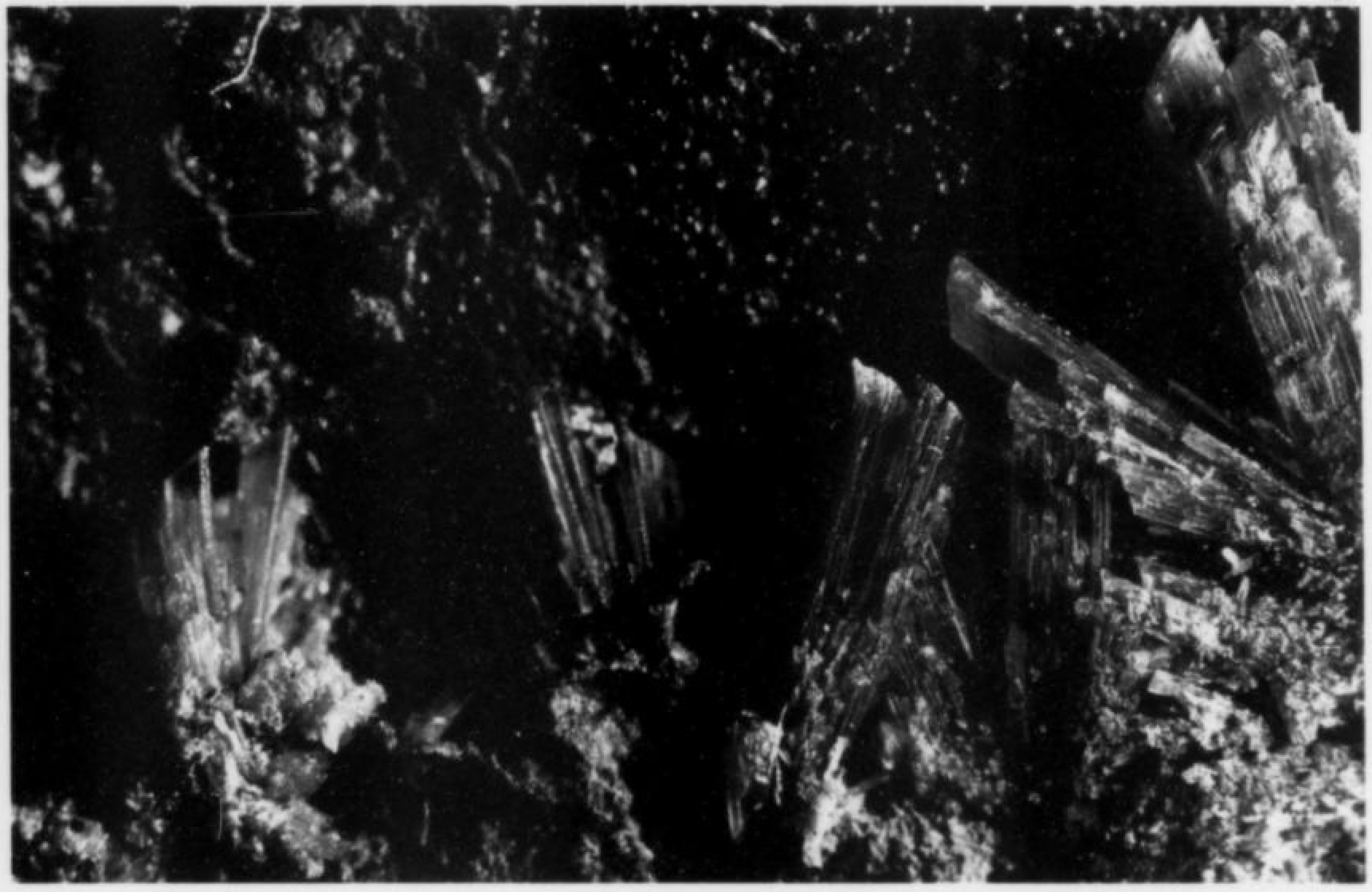
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Figure 6. Annabergite crystals to 3 mm.

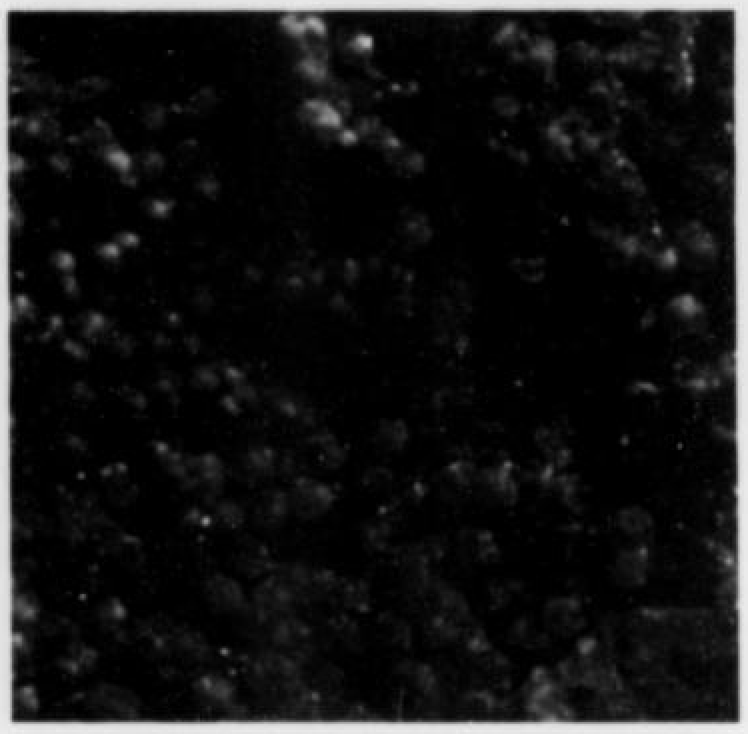

Figure 5. Spheroidal grains of glaukosphaerite (bright green) on a cavity wall in weathered ultramafic. The individual spheroids are about 2 mm in diameter. Photo by B. J. Gartrell.

Figure 7. Bright green kambaldaite crystals about 0.8 mm in length, on nodular gaspeite from the upper part of the carbonate zone.

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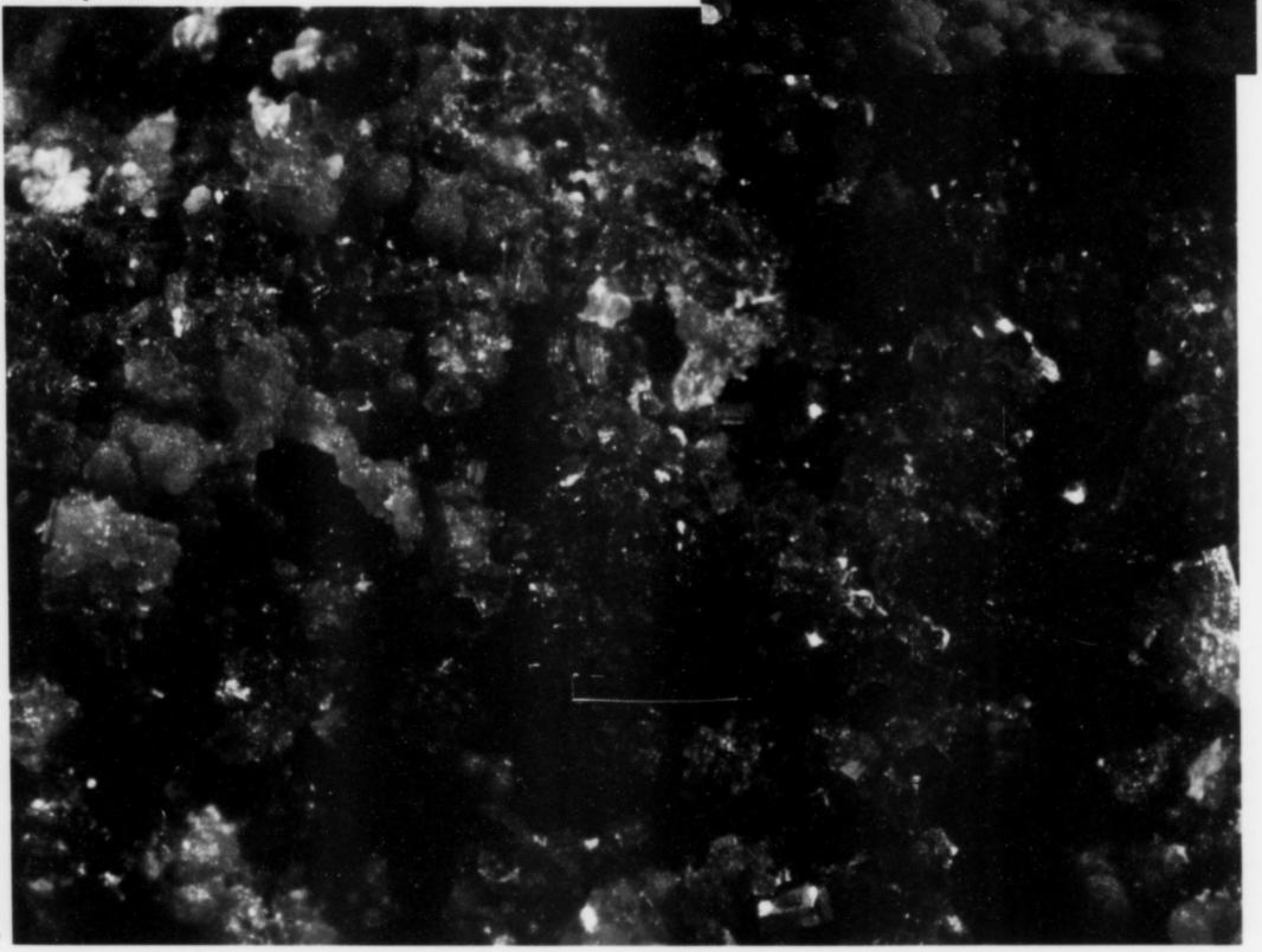

Figure 8. Kambaldite crystals to 0.4 mm, from the upper part of the carbonate zone.

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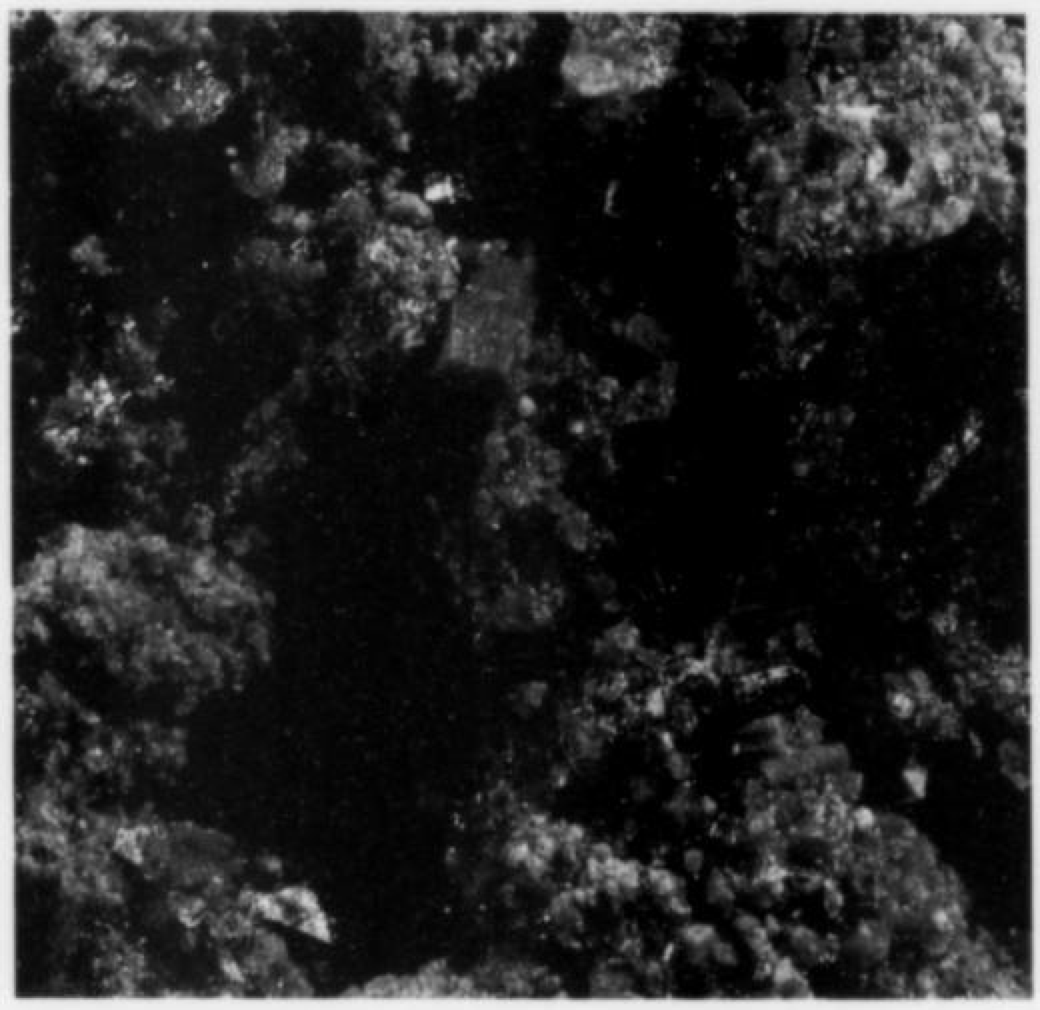

Figure 9. Nepouite crystals exhibiting pseudo-hexagonal morphology. The largest crystal is 6 mm long.

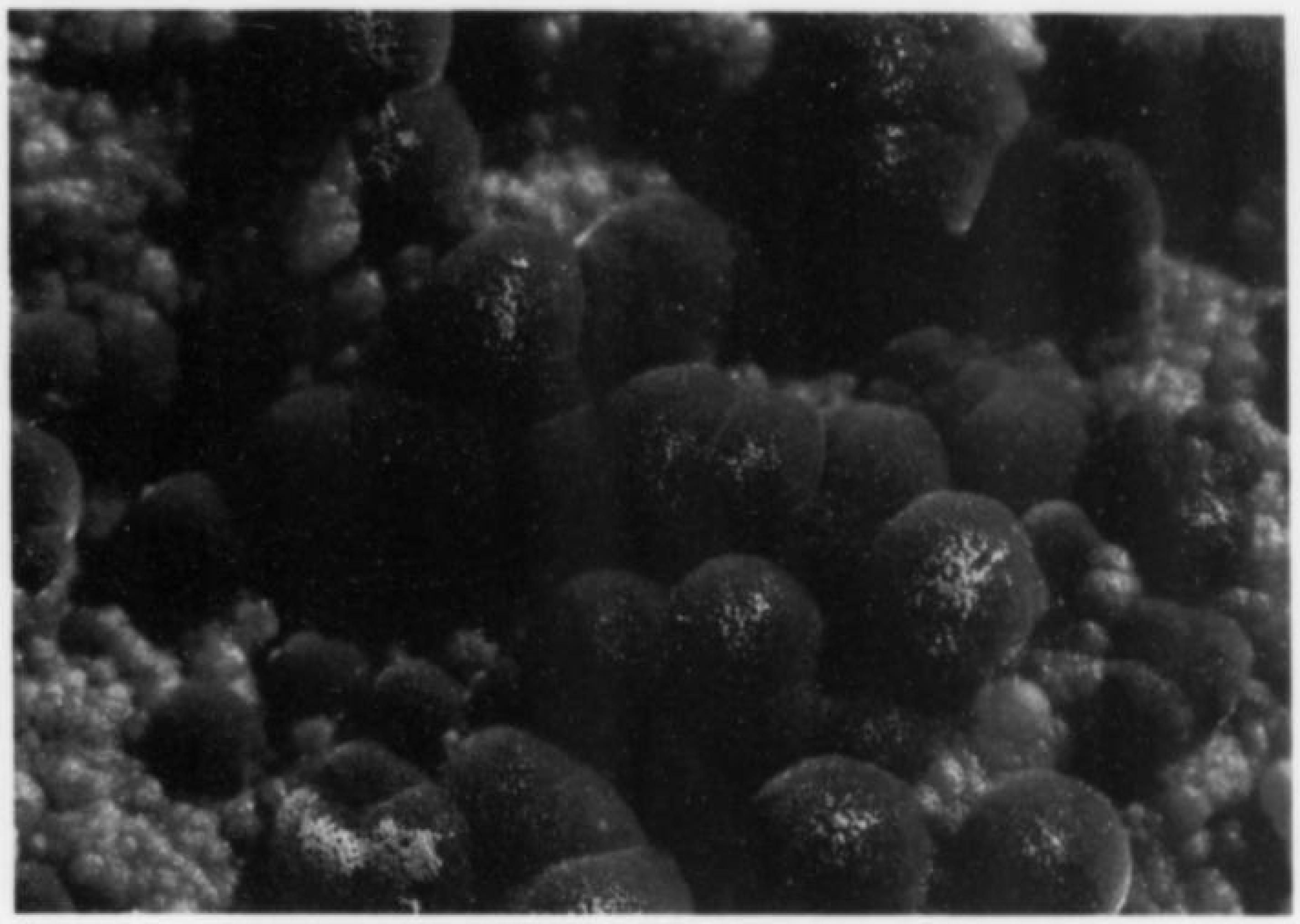

Figure 10. Cuprian nullaginite (dark green) on a vug surface in nickeloan gaspeite (yellow) from the lowermost section of the upper carbonate zone. The largest spheroid is 1.6 mm.

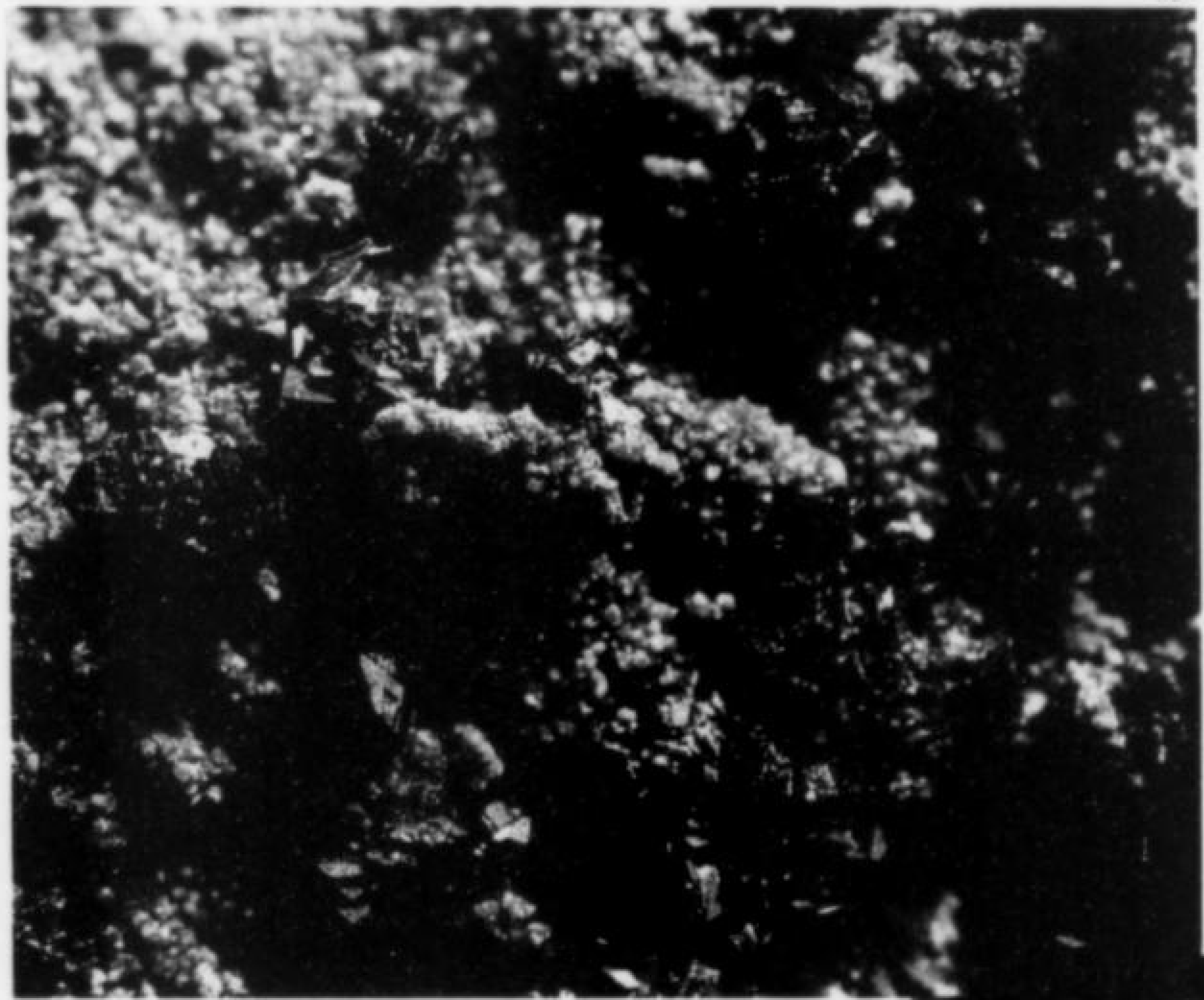

Figure 11. Dark green crystals of paratacamite to 0.5 mm on hydrohonessite.

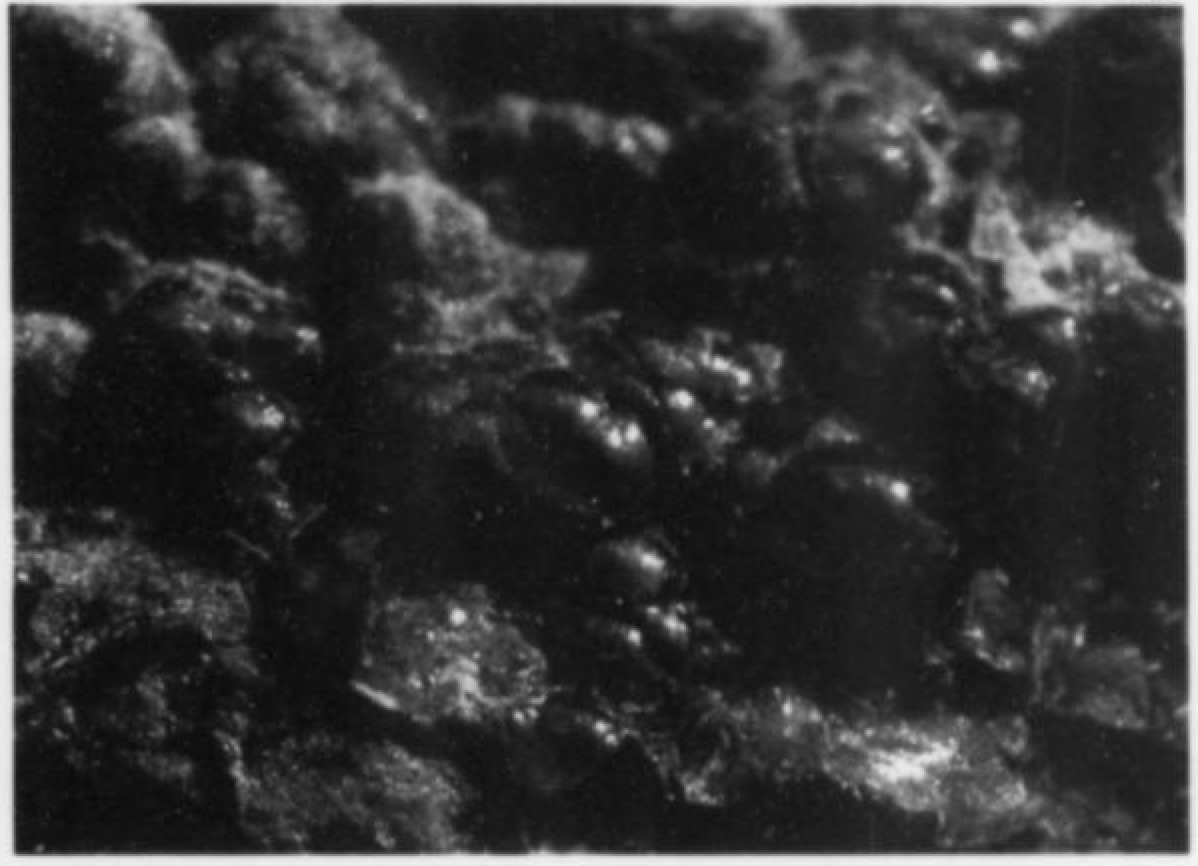

Figure 12. Unnamed vitreous hydrous nickel carbonate.

Figure 13. Fractured 3-mm widgiemoolthalite spheroids on gaspeite.

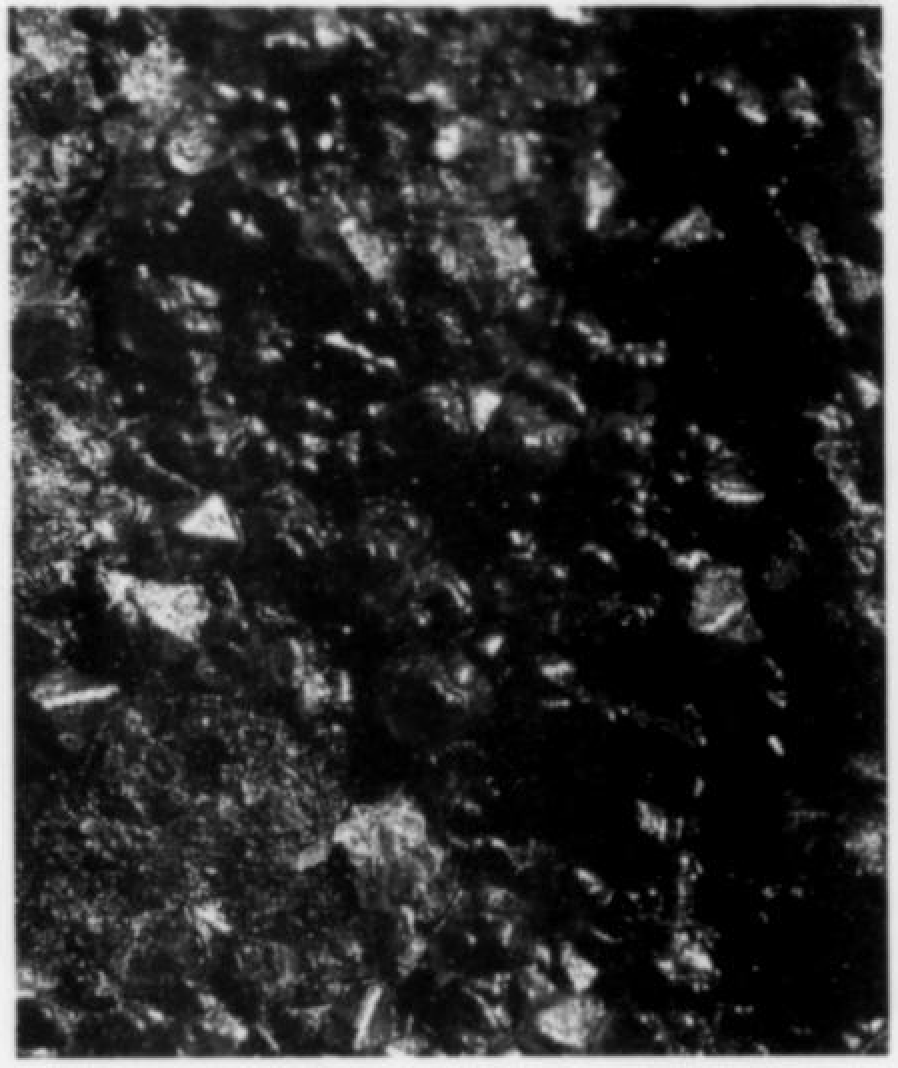

Figure 14. Pecoraite crystals to 0.5 mm.

in size. On one specimen "bow tie" crystals up to 1.5 mm in size were seen. Another manifestation of kambaldaite is a pale green powder. Under the SEM this powder is seen to consist of microcrystalline needles. Some of the kambaldaite specimens from this deposit represent the best material seen to date.

Magnesite (nickeloan) $MgCO_3$

Relatively pure white magnesite appears to have been the first secondary mineral to have been deposited in openings formed by the dissolution of the nickel sulfides at the bottom of the carbonate zone. In the lower part of the zone it occurs as thin discontinuous margins on gaspeite veins, whereas higher up it tends to occur as dense coatings on cavity surfaces where it forms a substrate for the deposition of later secondary minerals. Greenish nickeloan magnesite, representing a solid solution between magnesite and gaspeite, generally appears to have been deposited later, in the upper part of the carbonate zone, and overlies the white magnesite.

Nepouite $Ni_3Si_2O_5(OH)_4$

Nepouite, the nickel analog of the serpentine mineral lizardite, was seen in abundance in a few specimens of disseminated ore in the upper part of the carbonate zone. In one specimen it occurs as a band of heavily disseminated grains in a pale altered serpentinite. In another, it was observed as vuggy clusters of crystals lining a solution cavity. Nepouite is dull green, and characteristically occurs as crystals with a hexagonal aspect and a pronounced foliation normal to the "hexagonal" crystal axis.

Electron microprobe analyses (average of 6) of nepouite gave a composition corresponding to $Ni_{2.82}Mg_{0.05}Fe_{0.02}Al_{0.03}Si_{2.08}(OH)_{4.00}$, which is close to its ideal chemical formula.

Although nepouite has the same chemical formula as pecoraite (see below), its pseudohexagonal morphology and foliated aspect is in strong contrast to the fibrous nature of pecoraite. The XRD powder patterns of the two minerals, though broadly similar in appearance, are distinguished by the reflections in the region of 1.5Å. Pecoraite has one strong reflection at 1.53Å whereas nepouite has two reflections of about equal intensity at 1.53 and 1.50Å. This difference is analogous to that exhibited by their magnesium analogs clinochrysotile and lizardite.

Nullaginite $(Ni,Cu)_2(CO_3)(OH)_2$

As noted above, nullaginite and glaukosphaerite are believed to form a solid-solution series, and those specimens with Ni in excess of Cu (Table 4) can be called cuprian nullaginite. This cuprian nullaginite occurs in gaspeite vugs in the middle of the carbonate zone, mainly as bright green spherules up to about 1 mm in diameter and composed of radiating prismatic crystals, virtually identical in appearance to the majority of the glaukosphaerite. Nullaginite was first discovered in the Nullagine region of Western Australia (Nickel and Berry, 1981), and the occurrence of the cuprian variety at the 132 North deposit represents the second known occurrence of the mineral.

Olivenite $(Cu,Ni)_2AsO_4(OH)$

Olivenite of typical olive-green color has been found in only a few specimens. End-member olivenite contains Cu as the only cation, although zincian varieties are common, leading to the zinc end-member, adamite. However, EDS spectra of the olivenite from this occurrence show that nickel substitutes for some of the copper. In one specimen, prismatic crystals up to 1 mm in length produced spectra indicating a Cu:Ni ratio of about 6:1. In another, equant crystals gave spectra indicating a Cu:Ni ratio of about 1.7:1 which, to the best of our knowledge, represents the highest nickel content ever reported for olivenite.

Otwayite $Ni_2CO_3(OH)_2 \cdot H_2O$

Otwayite was originally discovered by the Otway nickel prospect in the Nullagine region of Western Australia (Nickel *et al.*, 1977b), and a second occurrence has recently been reported from Tasmania (Henry and Birch, 1992); its occurrence at the 132 North deposit is the third known occurrence.

Otwayite is a rare mineral at Widgiemooltha, being positively identified in only two specimens. In one of them it occurs as a thin bluish green coating on botryoidal gaspeite; in the other, it occurs as bluish green spherules.

Table 5. **Electron microprobe analyses of nickeloan paratacamite.**

Anal. no.	52839	52840	52852	52781	52775	Theoretical $Cu_2Cl(OH)_3$
Cu	51.2	49.7	46.8	43.4	43.0	59.51
Ni	8.0	10.2	13.0	14.5	17.4	—
Cl	16.6	16.7	16.4	17.0	14.4	16.60
OH	24.2	23.4	23.8	25.1	25.2	23.89

Paratacamite $(Cu,Ni)_2Cl(OH)_3$

Nickeloan paratacamite is present throughout the carbonate zone, and is a relatively abundant mineral at the top of the zone. It occurs as clusters of dark green, almost black, crystals up to several millimeters in size, on a substrate of gaspeite or magnesite. The nickel content, as determined by microprobe analyses, is up to 17.4% Ni (Table 5), probably the highest nickel content for this mineral reported to date.

Pecoraite $Ni_3Si_2O_5(OH)_4$

Pecoraite, the nickel analog of clinochrysotile, is quite abundant toward the top of the carbonate zone. It occurs as bright green coatings on cavity walls in the vuggy gaspeite, and as fracture fillings, sometimes intergrown with other nickel silicates. In transmitted light under the microscope pecoraite has a fibrous texture, which contrasts with the foliated nature of its polymorph, népouite.

Reevesite $Ni_6Fe_2(CO_3)(OH)_{16} \cdot 4H_2O$

Reevesite appears to be a rare mineral at Widgiemooltha. It was positively identified in only a few specimens, as yellow powder and tiny yellow crystals, quite similar in appearance to the more abundant hydrohonessite.

Retgersite $NiSO_4 \cdot 6H_2O$

Retgersite occurs as a minor phase, often associated with goethite, at the top of the violarite-pyrite zone. It is absent from the lower part of the carbonate zone, but is seen again at the top of the carbonate zone, a distribution that is undoubtedly a function of this mineral's solubility in water. It occurs mainly as thin, waxy, pale blue surface coatings, but in one specimen well-developed pale blue crystals up to 2 mm in size were observed.

Takovite $Ni_6Al_2CO_3(OH)_{16} \cdot 4H_2O$

Takovite has been observed in a few specimens from the upper part of the carbonate zone, mainly as a pale blue to bright bluish green coating on fracture surfaces. In one specimen it occurs as spheroidal bluish green grains consisting of radiating fibers, very similar in appearance to widgiemoolthalite.

Widgiemoolthalite $Ni_5(CO_3)_4(OH)_2 \cdot 5H_2O$

Widgiemoolthalite from this occurrence was recently described as a new mineral (Nickel *et al.*, 1993). It occurs toward the base of the carbonate zone as silky bluish green spheroids composed of radiating fibers. The spheroids average about 0.5 mm in diameter, with the largest being about 2 mm. The individual fibers comprising the spheroids are only a few micrometers in diameter.

Unnamed fibrous nickel carbonate

A fibrous bluish green mineral that occurs mainly as asbestiform cross-fiber veinlets produces an X-ray diffraction pattern similar to

Table 6. **Electron microprobe and CHN analyses of unnamed minerals.**

	Weight Percentages			*Atomic Proportions*	
	1	2		1	2
NiO	45.1	60.2	Ni	4.75	4.86
MgO	1.3	0.4	Mg	0.25	0.06
CaO	nd	0.7	Ca		0.08
CO_2	34.1	27.3	C	6.08	3.75
SO_3	nd	1.2	S		0.09
H_2O	21.5	12.0	H	18.73	9.00
	102.0	101.9.0			

1: Fibrous mineral; microprobe analysis by G. J. Hitchen; C and H analyses by CHN analyzer.

2: Vitreous mineral; microprobe analysis by W. D. Birch; C and H analyses by CHN analyzer.

that of widgiemoolthalite, but microprobe and CHN analyses indicate more CO_2 and H_2O and less NiO (Table 6). To obtain charge balance it is necessary to calculate some of the CO_2 as HCO_3, giving the following formula: $(Ni,Mg)_5(HCO_3)_2(CO_3)_4 \cdot 8.4H_2O$, on the basis of 5 (Ni + Mg). Attempts to measure the specific gravity of this mineral by the usual sink-float procedure in heavy liquids, gave variable results, possible due to entrapped air between the fibers. The maximum value obtained was 3.24.

The optical properties of this mineral could not be fully characterized because of the small diameter of the fibers, but the indices of refraction are 1.66 parallel to the fiber length, and 1.65 normal to the length. This means that the mineral is optically length-slow, in contrast to the optical character of widgiemoolthalite which is length-fast.

Unnamed vitreous nickel carbonate

A vitreous emerald-green mineral, similar to descriptions of the discredited mineral zaratite, occurs as a late-stage coating on some specimens. It is optically isotropic with a refractive index of 1.61. The chemical composition of the mineral, determined by microprobe and CHN analyses (Table 6), suggests the formula $Ni_4(CO_3)_3(OH)_2 \cdot 2.5H_2O$. The X-ray diffraction pattern contains only a few diffuse reflections, as follows (d(Å), Int.): 5.95(10), 3.33(5), 2.10(3), 2.25(2), 2.58(1), 2.42(1) and 1.97(1). These reflections could not be indexed, and could not be correlated with any diffraction data in the literature.

Associated Species

Aragonite crystals to 1.5 cm, azurite as surface coatings and dark blue crystals, calcite crystals to 1 cm, gypsum crystals and aggregates, massive white huntite, superb lavendulan crystals to 1 mm having a bright sky-blue color, pharmacosiderite fracture coatings, pyrolusite nodules and fracture coatings, and of course the ubiquitous quartz-goethite gossan material occur in association with the secondary nickel minerals. The EDS spectrum of the pyrolusite suggests an appreciable nickel content.

DISCUSSION and CONCLUSIONS

The Yilgarn Archean craton, in which the 132 North deposit is located, has remained a stable land mass probably since the late Paleozoic, and the supergene profile at the deposit is the product of weathering during the long period of time from at least the Permian period to the present. Weathering was a multi-stage process starting with the conversion of the original primary sulfides to a secondary sulfide assemblage (violarite-pyrite), probably as the result of anodic oxidation (Nickel *et al.*, 1972; Thornber, 1975a, b).

Further anodic oxidation reactions at the top of the violarite-pyrite zone resulted in the decomposition of the sulfides, which created a localized low-pH environment (Thornber, 1975a). Just above this region, in a zone of higher pH created by the cathodic reduction of dissolved oxygen radicals in the groundwater, carbonate minerals, mainly magnesite and gaspeite, were deposited, forming the carbonate zone. Decreasing pH higher in the weathering profile, attributable to the oxidation and hydrolysis of Fe^{2+} (Thornber, 1975b; Mann, 1983) caused the partial dissolution of these carbonates, leaving vuggy openings for the precipitation of the suite of rare minerals in the upper part of the carbonate zone.

The carbonate zone documented in this paper also occurs in a number of other deposits in the Widgiemooltha-Kambalda area, and has important implications for exploration.

The final stage in the development of the supergene profile, occurring at the top of the water table, was the dissolution of the secondary minerals and the precipitation of goethite and quartz, forming the surface gossan as its exists today. The relicts of sulfide textures observed in some specimens can be attributed to the replacement of sulfides by goethite and quartz below the carbonate zone due to fractures carrying highly oxygenated water down into the violarite-pyrite zone. Such relict textures are observed chiefly in the gossanized matrix or disseminated ore where the sulfide dissolution was delayed by the armoring of sulfides by silicates.

ACKNOWLEDGMENTS

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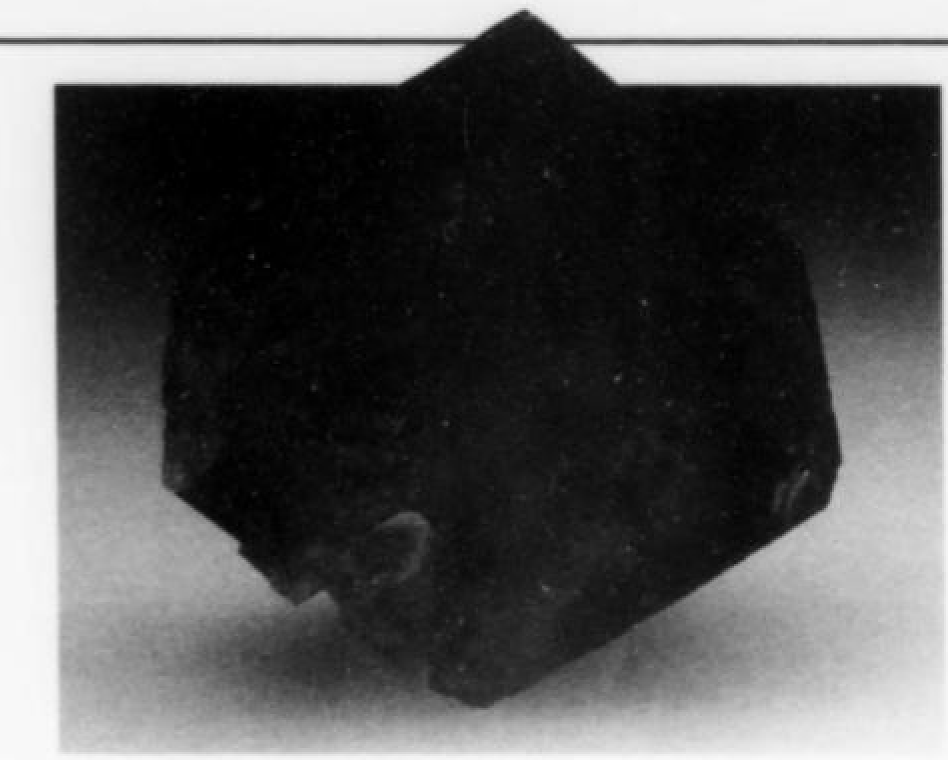

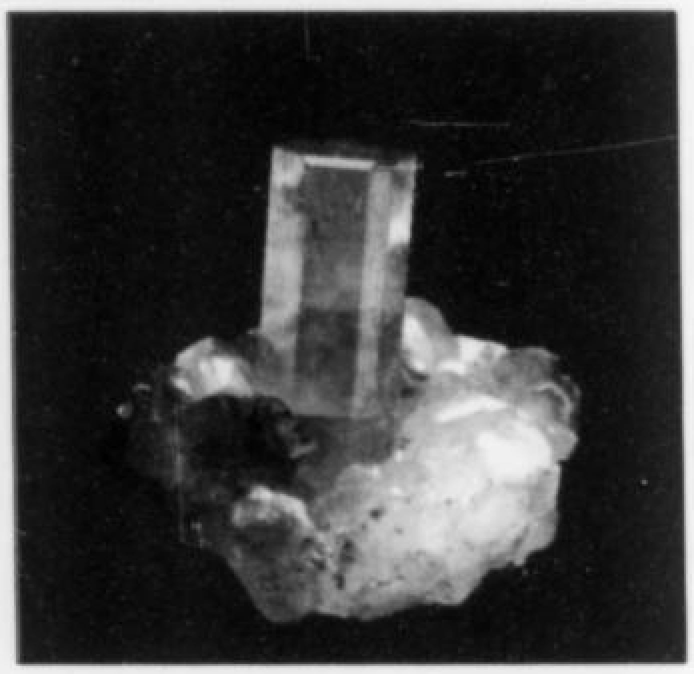

Topaz, Dusso, Gilgit, Pakistan

MINERALS OF THE UPPER ARNO RIVER VALLEY

TUSCANY, ITALY

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Some interesting mineralization has been discovered relatively recently in the coal mines of the upper Arno River Valley. Species found thus far include anapaite, vivianite, kutnohorite, and the white hydrocarbon mineral hartite, $C_{20}H_{34}$.

INTRODUCTION

The upper Arno River Valley (Upper Valdarno) basin lies 30 km southeast of Florence and spreads out between the Chianti hills to the west and the Pratomagno Mountains to the east. The basin stretches northwest-southeast for about 35 km, and has a breadth of 15 km; it is easy to reach traveling on the A1 Highway, and leaving the highway at the "Valdarno exit."

In this present work, the mineralogy of two distinct areas will be described: one refers to the Santa Barbara lignite mining area, indicated with code SB; the other concerns the locality named Levane, designated by the code LV.

At the Santa Barbara mine, over the past 20 years, fairly good specimens of anapaite, vivianite and gypsum have been found. The mine management must be asked, but is usually willing to give collecting permission to visitors who wish to enter the mining zone.

Near Levane, aragonite and kutnohorite in calcareous nodules are the only minerals to be found. Because the minerals occur on agricultural land, it is necessary to obtain permission from the landowner before collecting these.

HISTORY

The Upper Valdarno is known among scientists for its large mammal fossils and extensive deposits of lignite. In the last decade, interesting mineralization connected with geological and mineralogical features has been discovered—the subject of this study.

The peculiarities of this area had already been observed by Leonardo da Vinci, who wrote about it in his unpublished *Atlantic Codex*, dated 1488–1518. We then must wait for Giovanni Targioni Tozzetti (1712–1783) in order to get a more accurate description of this area. Tozzetti was followed by other scientists who, in time, facilitated the exploitation of the lignite deposit.

With the beginning of the open-pit mining method it has been possible to reach strata which are important from a mineralogical viewpoint. The exploitation began in 1867 with drilling. Throughout the years 1878–1890, 11 mines were opened, five of them managed by Società Ferriere Italiane. After a series of events the management of the mine was taken over in 1920 by Società Valdarnese Miniere Lignitifere and by Società Elettrica Toscana (SELT). SELT then took over all the works which, from that time on, were to be only open-pit mined. In the mid-1960's the ENEL (National Electricity Board) became solely responsible for the production and distribution of electricity in Italy, and replaced SELT in the management of this important source of energy. The annual production of lignite today is about 1.5 million tons; lignite is used to fuel a 250-megawatt thermoelectric power plant situated at Castelnuovo dei Sabbioni.

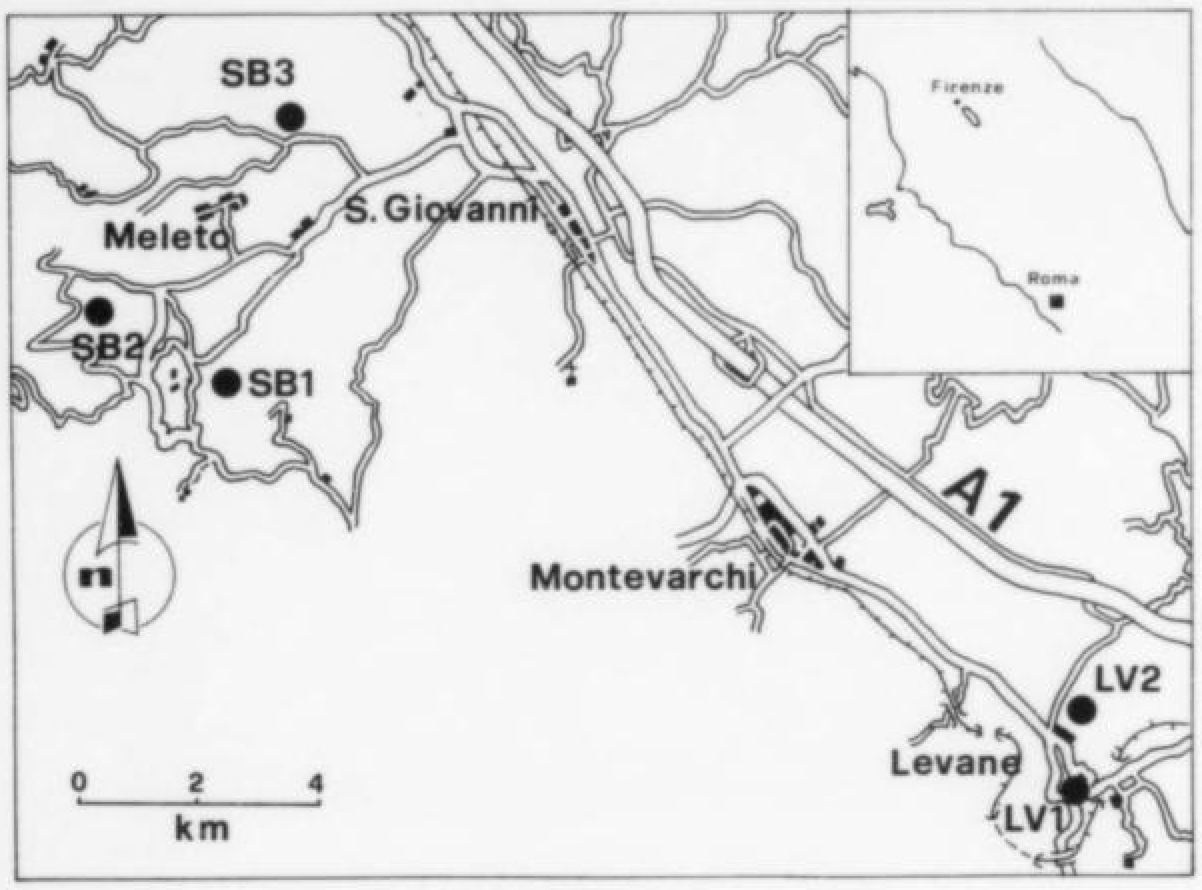

Figure 1. **Location map.**

Figure 2. **View of the Allori mine (SB2). Lignitiferous basin at Santa Barbara.**

GEOLOGY

Throughout the Upper Miocene, the inner part of the Northern Apennines and Tyrrhenian basin was affected by tensional faulting causing an uplift of positive areas and subsidence of basins (Trevisan, 1952; Elter *et al.*, 1975; Boccaletti *et al.*, 1990). The development of eastern basins begins in the Pliocene and continues during the Pleistocene. The deposits, owing to the infilling of the basins, are formed by fluviatile and fluviatile-lacustrine sediments, more coarsely textured toward the margin, and up to 800 meters thick (Sestini, 1970; Bartolini *et al.*, 1982). Within the stratigraphic succession, unconformities, erosion surfaces and hiatuses are often present, in agreement with the uplifting of the Apennine chain.

The Upper Valdarno fluviatile-lacustrine basin is filled by sediments up to 550 meters in thickness; their age ranges from Upper Pliocene to Middle Pleistocene (Merla, 1949; Abbate, 1983). The basin substrate is composed of Oligocene sandstones, called the Macigno Formation, toward the southern margin; the northward substrate changes into Miocene Cervarola sandstones.

The basin shows an accentuated structural asymmetry: the northeastern margin is much more tilted and faulted than the southwestern one (Sagri, 1991). Sedimentary and tectonic evolution of the basin and its filling occurred in three stages, with the development of three stratigraphic successions (Merla and Abbate, 1967; Azzaroli and Lazzeri, 1977; Lazzarotto and Liotta, 1991). These cycles are separated by clear limits represented by unconformities, hiatuses and erosion surfaces extended throughout the basin.

First stage (Upper Pliocene)

Tectonic movements that gave rise to the Upper Valdarno basin began in Upper Pliocene and started with the development of two small basins localized in the Castelnuovo and Palazzolo areas, near the edge of the Chianti hills. First stage deposits are, from the bottom to the top: (1) Spedalino pebbles and sands (50 meters); (2) Meleto clays (200 meters): interbedded silts, fine sands and clays abounding in vegetable remains; and (3) San Donato sands (80 meters). First-stage sediments are quite rich in fossil flora and vertebrate fauna that denote a humid-hot climate (Marcucci, 1970; Azzaroli, 1984).

Second stage (Upper Pliocene–Lower Pleistocene)

This phase began after the first-stage sediments were deformed and tilted toward the northeast. A lacustrine-palustrine environment toward the interior, and alluvial fan conditions at the edges of the basin, were created (Billi *et al.*, 1991). Horizontal sediments of the Montevarchi series are in angular unconformity with the former series. They consist of, from the bottom to the top: (1) Terranova silts (250 meters): silts and sands; (2) Torrente Ascione clays (5–20 meters): silty clays rich

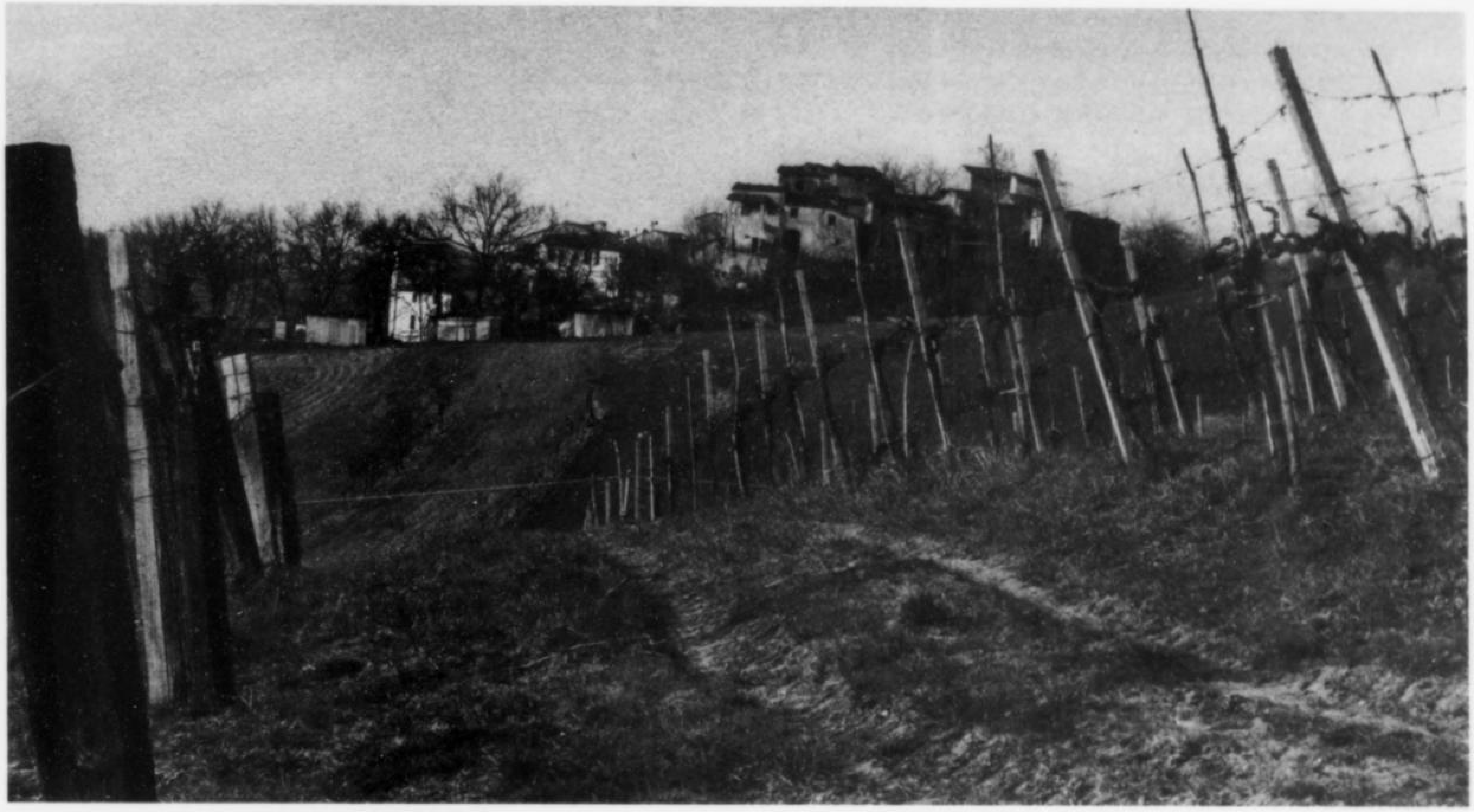

Figure 3. **View of the site LV2. Here the best specimens of kutnohorite have been found.**

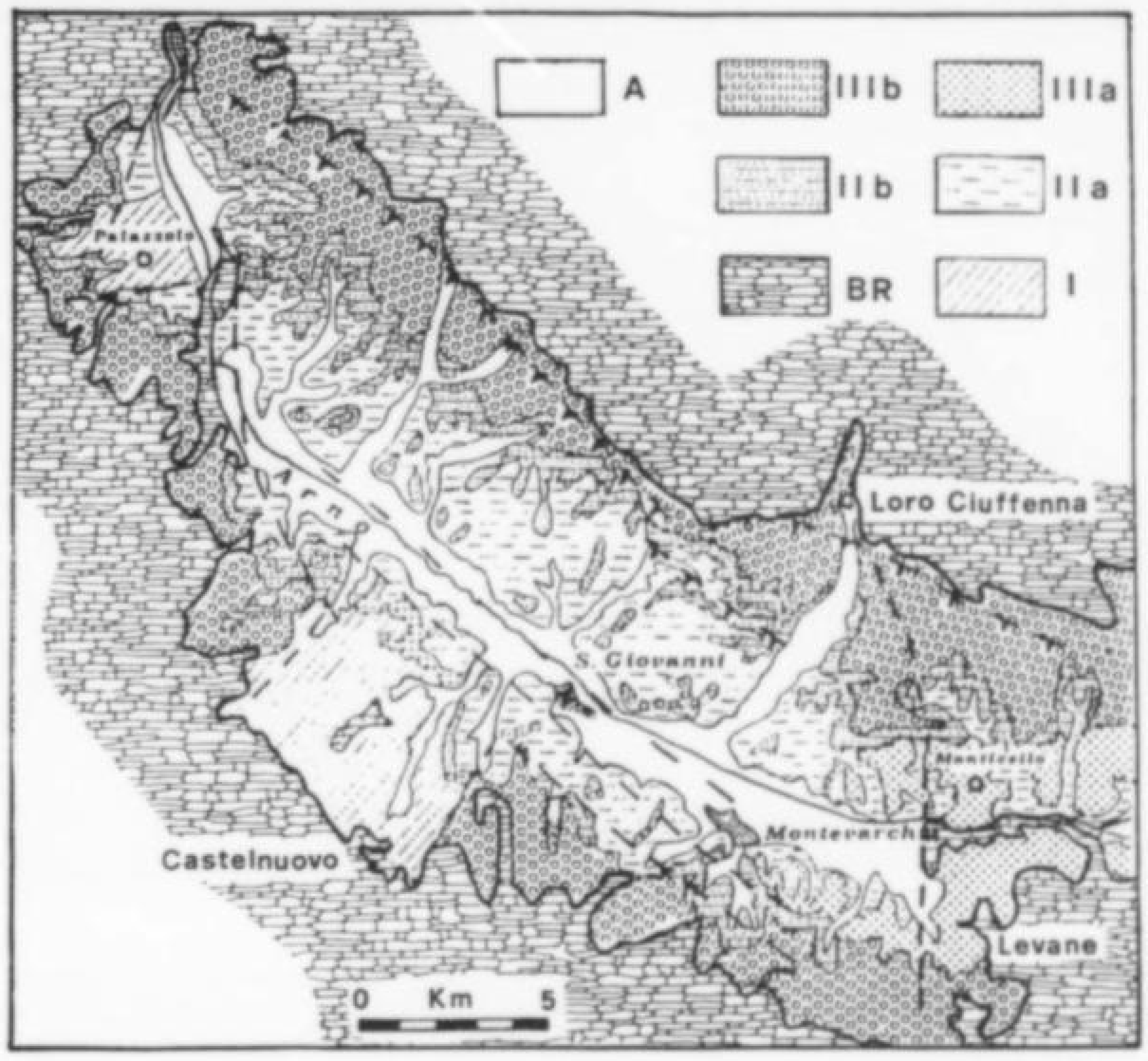

Figure 4. **Geological sketch of the Upper Valdarno. (Modified after Sagri and Magi, 1992).**

- **A: alluvium and terraces.**
- **III: third stage (Middle Pleistocene); a: Monticello fluvial deposits, b: alluvial fan deposits in the Ciuffenna River.**
- **II: second stage (Upper Pliocene–Lower Pleistocene); a: lacustrine-palustrine deposits, b: alluvial fan deposits.**
- **I: first stage fluviatile-lacustrine sediments (Upper Pliocene).**
- **BR: bedrock.**

in peat; and (3) Oreno silts and sands (50 meters).

Uplifting of the Chianti and Pratomagno ridges produced the formation of broad alluvial fans, especially in the northeastern margin. The deposits resulting from this uplift, from bottom to the top, are as follows: (1) Penna pebbles (50 meters); (2) Casa la Querce pebbles and sands (40–50 meters); and (3) Borro Cave sands (30 meters).

The Montevarchi series is rich in large mammal fossils (Azzaroli,

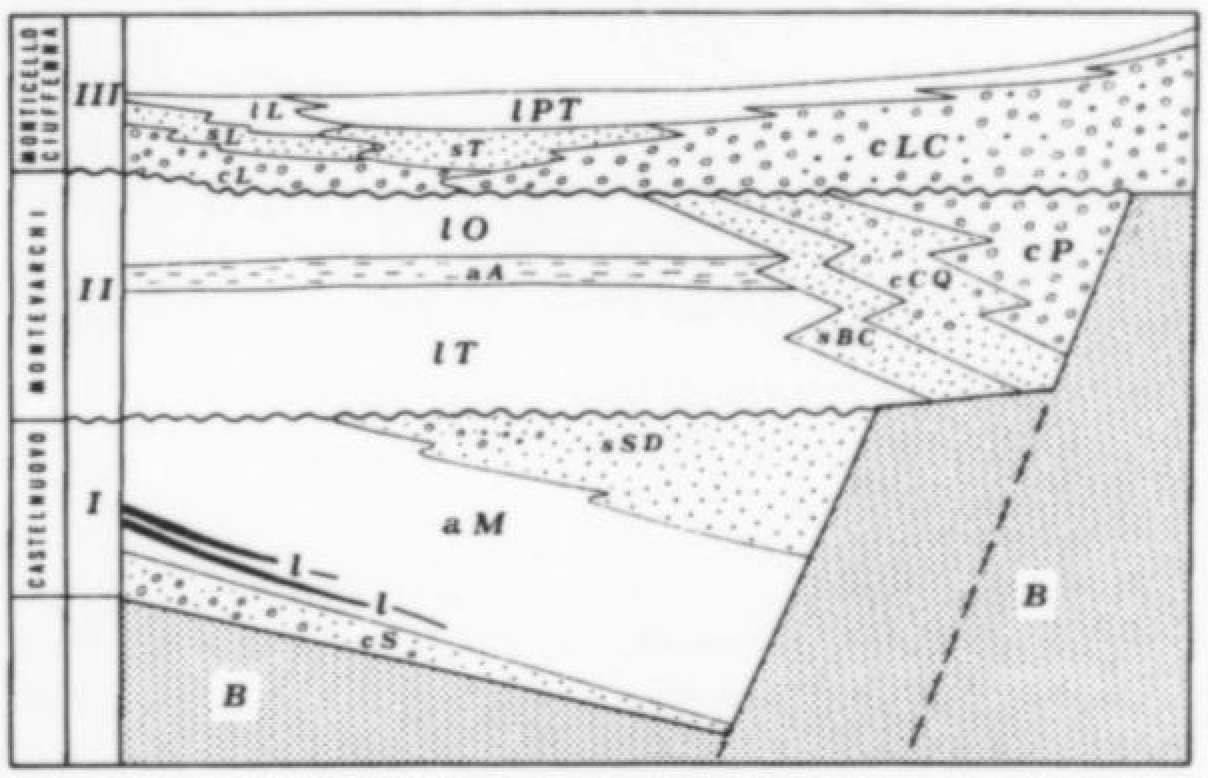

Figure 5. (left) **Lithostratigraphic sequence showing the Upper Valdarno fluviatile-lacustrine sediments (after Sagri and Magi, 1992).**

- **III: third stage (Middle Pleistocene); lL: Latereto silts, sL: Levane sands, cL: Laterina pebbles, lPT: Pian di Tegna silts, sT: Tasso sands, cLC: Loro Ciuffenna pebbles.**
- **II: second stage (Upper Pliocene–Lower Pleistocene); lO: Oreno silts and sands, aA: Torrente Ascione clays, lT: Terranova silts, sBC: Borro Cave sands, cCQ: Casa la Querce pebbles and sands, cP: Penna pebbles.**
- **I: first stage (Upper Pliocene); sSD: San Donato sands, aM: Meleto clays, l: lignite beds, cS: Spedalino pebbles and sands.**
- **B: bedrock.**

1977; De Giuli, 1983). Pollens from the upper portion of the Montevarchi series indicate a fresh-humid climate with some periods of dryness. Great tectonic movements gave rise to a large supply of clastic material that caused the silting up of the lake.

Third stage (Middle Pleistocene)

Third-stage deposits lie on the second-stage sediments with a slight angular unconformity and, moreover, the transition is marked by paleosol remnants. In the inner part of the basin the two successions are unconformable due to an erosion surface. The third stage began with a drastic change of fluviatile drainage. The paleoArno leaves a narrow belt of sediments, called the Monticello deposits (30–50 meters), made up, from bottom to top, of: (1) Laterina pebbles; (2) Levane sands: medium to coarse sands; and (3) Latereto silts: massive silts pedogenized (turned to soil).

In this phase a heavy supply of coarse sediments from the steep sides of the basin continued. They formed the alluvial fan deposits of the Ciuffenna River, and are composed, from bottom to top, of: (1) Loro Ciuffenna pebbles (20–50 meters): massive pebbles with interbedded sands and silts; (2) Tasso sands (10–30 meters): medium to coarse sands; and (3) Pian di Tegna silts: clayey silts interbedded with sands and fine pebbles heavily pedogenized.

The last phase continued into the Pleistocene-Holocene, with the erosion of the upper Valdarno sediments and consequent shaping of stream terraces along main rivers.

MINERALS

Anapaite $Ca_2Fe(PO_4)_2 \cdot 4H_2O$

Anapaite is an uncommon phosphate previously known from a few localities, among which are Anapa, on the Black Sea, Russia; Prats-Sampsor (Spain); Kings County, California; and Messel (Germany).

At site SB1 and SB2 (the Castelnuovo and Allori mines), anapaite has been found as layered deposits inside the Meleto clays. It was studied independently by Cipriani *et al.* (1974) and by De Michele *et al.* (1974), who performed morphological and chemical analyses.

Anapaite occurs as radiating masses with variable shape and size. The interior contains many cavities filled by aggregates of triclinic tabular crystals. The crystals are green or yellow-green, translucent, vitreous, and a millimeter or two in size.

A gradual change in the character of the masses, with regard to their position inside Meleto clays, may be noted: in the uppermost part there are small nodules, nearly spherical and about 1 cm in diameter, progressing to nodules as large as 10 cm in diameter in the lower part. The anapaite nodules often appear joined together to form a compound cluster. At the bottom of the formation of Meleto clays, near the Macigno Sandstone, layers of anapaite with a thickness of from 5 to 20 cm and an extension of tens of meters occur.

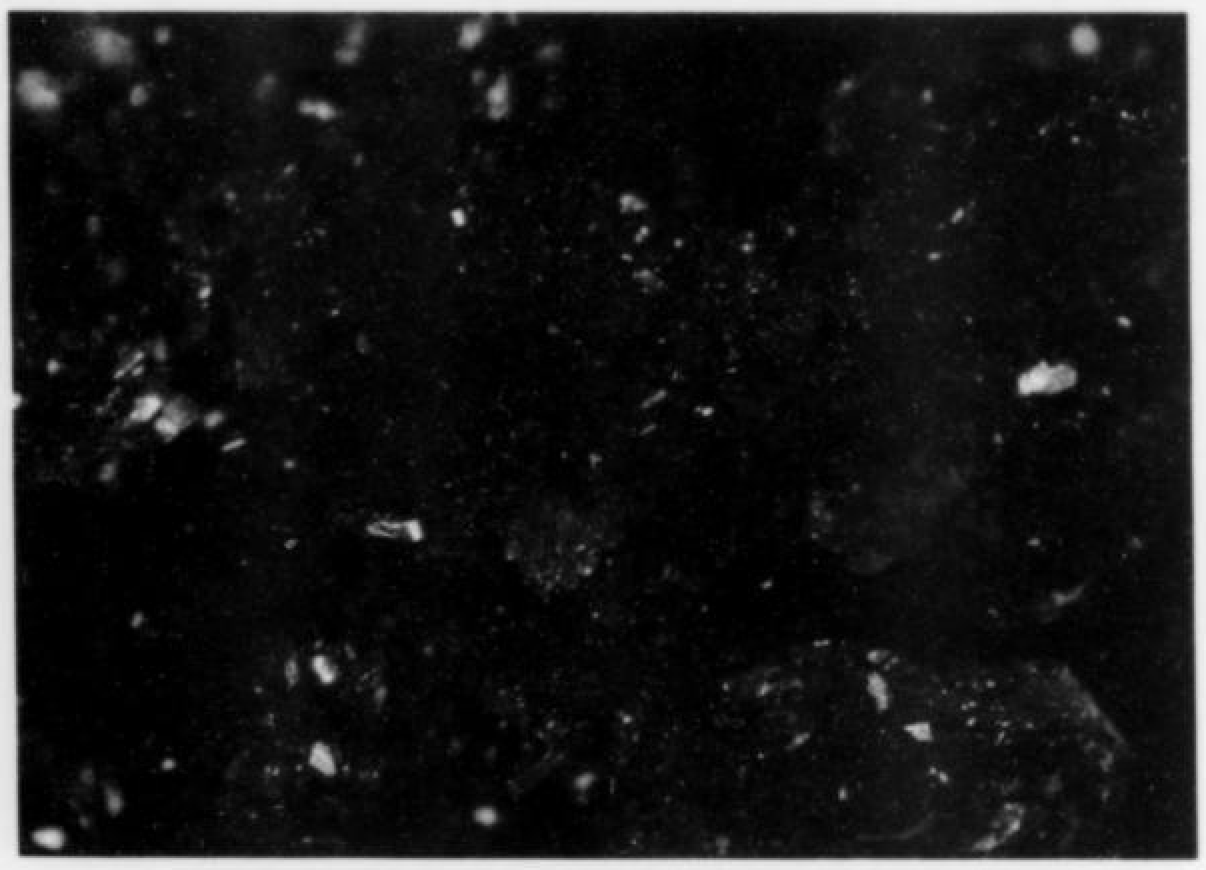

Figure 6. **Anapaite crystal group; site SB1. The field of view is 5 mm across.**

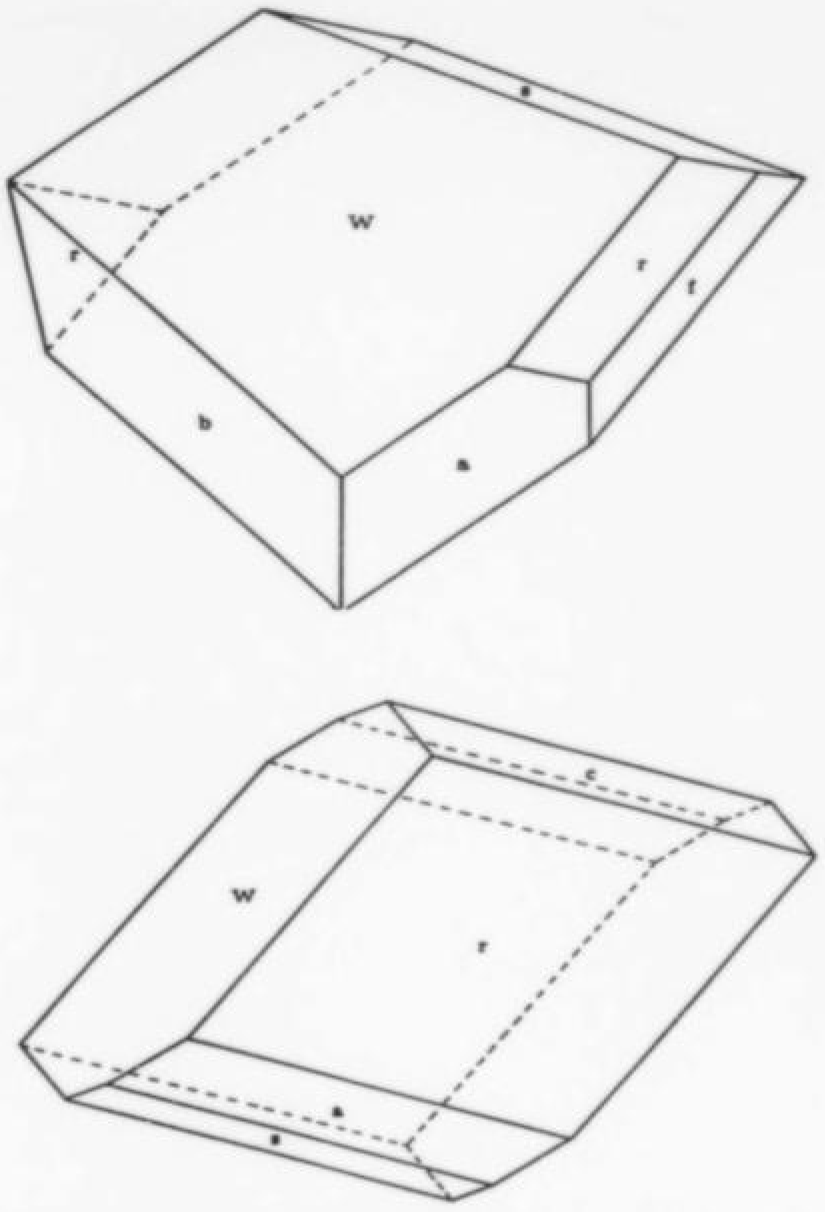

Figure 7. **Crystal drawings of anapaite showing the commonly observed forms *a*{100}, *b*{010}, *c*{001}, *f*{110}, *r*{101}, *s*{101} and *w*{011} (after De Michele *et al.*, 1974).**

Aragonite $CaCO_3$

Aragonite is found, almost always associated with kutnohorite, in cavities inside carbonate nodules in the Terranova Silt Formation (LV1 and LV2 sites), in the second fluviatile-lacustrine stage. The nodules, ranging from 1 to 5 cm and consisting of silt cemented by calcite, have a different appearance according to their source: they have a smooth surface and a shell several millimeters thick at site LV2, whereas those coming from LV1 have a very thin shell (1–2 mm), with a cell-like surface, composed of aragonite only.

Figure 8. **Aragonite from site LV1. The view is 4 cm across. Lido Boanini specimen and photo.**

Aragonite occurs as fine, sharply pointed needles which are colorless transparent, vitreous, and often twinned; the crystals are sometimes flattened on {010} and often have a characteristic chisel shape (Bini and Menchetti, 1985).

Figure 9. **Yellow spherules of kutnohorite to 3 mm with acicular crystals of aragonite; site LV2. Lido Boanini specimen and photo.**

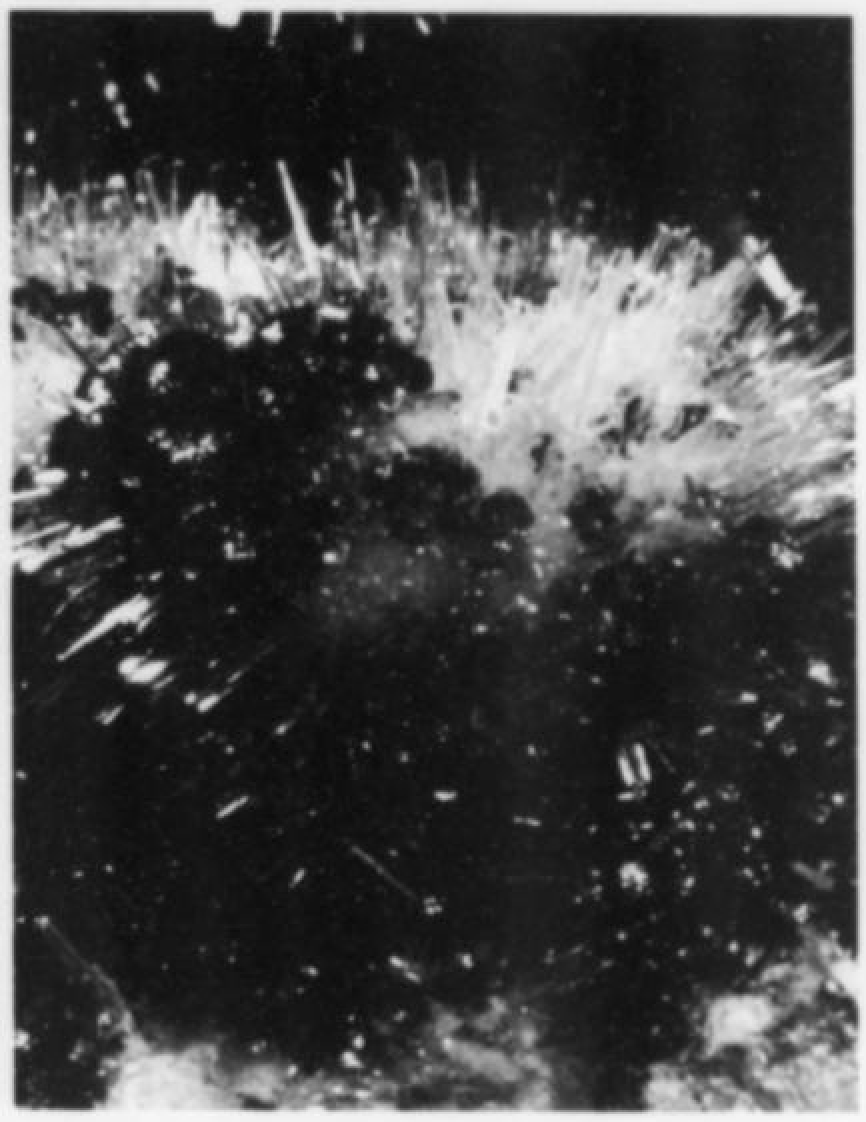

Figure 10. **Glossy black specimen of kutnohorite from site LV2. The field of view is 1 cm across. L. Boanini specimen and photo.**

Figure 11. **Hartite from site SB2. The view is 7 cm across. G. Ontelli collection; L. Boanini photo.**

Figure 12. **Vivianite crystals to 7 cm from site SB2. This is one of the best specimens of vivianite found in the Santa Barbara mining area. Giuseppe Ontelli collection; Lido Boanini photo.**

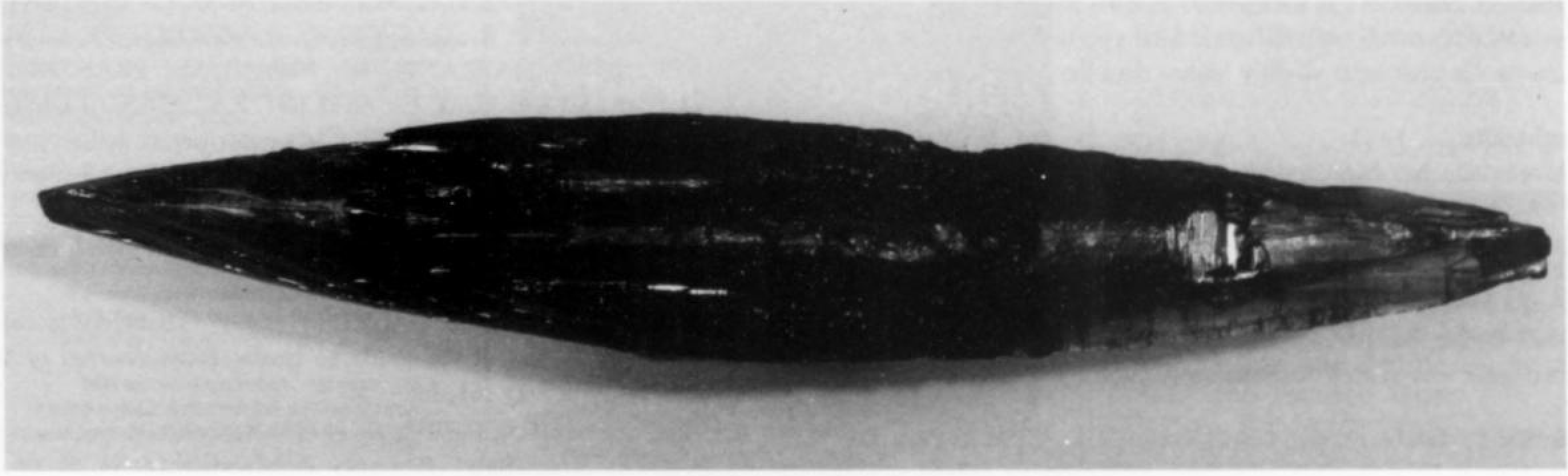

Figure 13. **A superb vivianite crystal, 20 cm; site SB2. G. Ontelli collection; L. Boanini photo.**

Barite $BaSO_4$

Barite was discovered in association with the more abundant anapaite, as thin, radiating, hemispherical, yellowish aggregates no larger than 1 mm.

Gypsum $CaSO_4 \cdot 2H_2O$

Gypsum is found within Torrente Ascione and the Meleto clays as individuals and groups of grayish crystals to several centimeters. Near the San Giovanni railway station, gypsum has been found as typical "swallow-tail" twins on {100}. Nevertheless the most interesting specimens are found set on a brick-like matrix which formed during lignite self-combustion, through clay baking and the consequent oxidation of ferrous minerals (Billi, 1980). Here the gypsum crystals, several centimeters in length, may be found as colorless, transparent, elongated individuals, often gathered into graceful groups.

Goethite $FeO(OH)$

Goethite forms very thin crusts on the surface of kutnohorite, imparting a deep black or brownish color.

Hartite $C_{20}H_{34}$

This organic compound was collected as a whitish coating on lignite by Bombicci (1869); it was later named after him by Bechi, as a new species, *bombiccite*. Studies performed by Ciusa and Galizzi (1921) were unable to confirm its identity. X-ray powder diffraction analyses by Pellizzer (1955) have classified the material as hartite. Detailed work concerning the structure was subsequently published by Foresti *et al.* (1978), who established this natural diterpene as having the alpha-dihydrophyllocladene structure.

Hartite occurs rarely as colorless, vitreous blades on the lignite; crystals are often grouped to form fibrous-radiating spherules on lignite.

Hematite Fe_2O_3

Hematite occurs as blackish, thin layers hosted by roasted clays; some hematite has a velvety texture produced by layers of microcrystals.

Kutnohorite $Ca(Mn,Mg,Fe)(CO_3)_2$

Kutnohorite from the Upper Valdarno was discovered in localities LV1 and LV2; it is always intergrown with aragonite, and like aragonite, it is found in cavities in the rounded calcareous nodules described previously. Kutnohorite occurs as rounded micromasses: its color is white but on the surface the color varies from white to yellow, red, brown and glossy-black; the size of the masses reaches a few millimeters. The micromasses are saddle-shaped, a feature typical of dolomite (which has the same structure as kutnohorite). Regarding colors, it is difficult to define their origin, with the exception of glossy-black due to iron and manganese oxide crusts. Specimens from LV1 and LV2 were studied by Bini and Menchetti (1985) by means of powder diffraction, chemical and differential thermal analyses, from which it was deduced that "this mineral has at least a partially ordered structure, while the Ca content is slightly higher than the ideal formula."

Maghemite Fe_2O_3

Maghemite has been found as massive brown specimens distinguished by a strong magnetic susceptibility.

Pyrite FeS_2

Pyrite is very rare at Valdarno. It was found as small crystalline masses during the underground mining operations (SB1) in stopes where there was gaseous exhalation (Castelli, 1921).

Siderite $FeCO_3$

Siderite at Valdarno was first noted by Grattarola (1876) as small crystals in lignite fissures (SB1). It can still be found, both within Meleto clays and the lignite layers, as lenses and nodules (Sagri and Magi, 1992); it is fairly rare as euhedral, yellowish brown microcrystals.

Sulfur S

Sulfur has been noticed very rarely as thin crusts and small masses associated with gypsum on an orange-red matrix (Brizzi *et al.*, 1991).

Vivianite $Fe_3(PO_4)_2 \cdot 8H_2O$

Vivianite has been found in the Santa Barbara mining area as distinct layers within the Meleto clays. It occurs in three different habits. The most common occurrence is as a replacement of vegetable organic matter; blue to dark blue, perfectly preserved leaves may be collected. The concretionary radiating nodules from site SB3 are also very attractive; they are blue, up to 7 cm in size and have cavities lined with bright blue vivianite crystals to 2 mm.

In 1990 the most recent find took place during excavation at site SB2. Vivianite was found as thin layers interbedded with clays. These same clays have yielded radiating slabs and single or grouped prismatic crystals as large as 20 cm, greenish blue and transparent.

DISCUSSION

According to Cipriani *et al.* (1974) and De Michele *et al.* (1974) the genesis of anapaite and vivianite is related to the contemporaneous sedimentation of organic matter and inorganic clastic matter. A great number of animal remains were also deposited. Owing to the physiochemical conditions existing underwater at the depositional surface, the bones in this reducing environment produced a gel (consisting of Ca^{2+} and PO_4^{3-}) that crystallized as anapaite. The relative abundance of Fe^{2+}, contributing to anapaite and vivianite formation, may be explained as the work of reducing bacteria of the kind found in peat basins.

Regarding the kutnohorite genesis, no hypothesis has yet been put forward; it can only be emphasized that this occurrence is interesting because the mineral has been found in a sedimentary environment (Bini and Menchetti, 1985).

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Letters

VANADIAN DRAVITE

The "chromian uvite" from Burma referred to in "What's New in Minerals" (vol. 25, p. 61) is in fact something more unusual. Robert A. Gault and Joel D. Grice of The Canadian Museum of Nature, Ottawa, were kind enough to analyze a sample of this material for me. The mineral contains virtually no chromium; the color is most likely due instead to vanadium. The amount present is quite modest (0.8% V_2O_5), so the mineral does *not* represent a new vanadian analog. Specimens of this mineral should be labelled "vanadian dravite," according to the investigators. Vanadian tourmaline is apparently quite rare, but has been reported previously from Primorye, Russia (*Canadian Mineralogist*, vol. 31, p. 352).

Mark N. Feinglos
Durham, North Carolina

"TYPE" TERMINOLOGY

The Geological Curators Group has recently set up a small terminology working group to look at various aspects of terminology in the management of geological collections. The aim of this is not to provide a "thou shalt do what we say" set of rules. Rather, we hope to publicize any existing nomenclature control among non-specialists, and to suggest guidelines in selected areas where no such agreed control exists, and where we think it might be useful. We may also comment on areas where we specifically think terminological control is inappropriate. In particular, we hope to provide a relatively sane geological input to the various museum regulatory and advisory bodies, which seem to be producing ill-thought-out documentation guidelines at a depressingly furious rate, at least in Britain.

Among the first things we are looking at are the usages of "type" terms in the geological sciences. We hope to publish a note giving a brief, but clear account of these, and to list the authoritative source references. As I understand it, the I.M.A. paper by Pete Dunn and Joe Mandarino is THE definitive statement on mineralogical types. I was interested to see therefore, the appearance of a new term, nekrotype, in the recent Greenland Issue. I have spoken to several colleagues about this, and no one has ever heard of the term before. Do you know anything about the history or future prospects of this term?

Dr. J. W. Faithfull
Hunterian Museum, Glasgow University

The I.M.A. has considered the matter carefully and has adopted only the terms holotype, cotype *and* neotype *as reported by Dunn and Mandarino (*Mineralogical Record, *vol. 19, no. 4). Petersen's list was composed some years ago, prior to the I.M.A. ruling, and was unfortunately not corrected for compliance before publication. We regret that the additional terms appeared in the Greenland Issue; it is normally our policy to conform with I.M.A. rulings. Ed.*

"ZENIKSITE" or "THENIKSITE"?

It was a great pleasure to find a very attractive new mineral, *szenicsite*, at the 1994 Tucson Show. I listened to Dr. Carl Francis's lecture on the new species at the Convention Center, and purchased some specimens directly from Mr. and Mrs. Szenics at the Discovery Inn. Since the new mineral has been named after both of them jointly, I asked them how to pronounce their name. He said "zeniks," but she said, "I say 'theniks,' because I'm Peruvian." So how should the mineral name be pronounced? My suggestion would be to go with "theniksite," because that would be the pronunciation of choice in Chile where the mineral was found. And it sounds better, at least to me.

H. Hori
Tokyo, Japan

What an interesting problem. I don't think *there has ever been a case before this, where a mineral was named jointly after two people of the same name who pronounce their name differently. Normally I would cite I.M.A. chapter and verse on a question involving official aspects of mineral names. However, oddly enough, the International Mineral Association has* never been asked *to rule on pronunciations so there is no "officially" approved way to say* any *mineral name!*

Back in 1955 Max Hey of the British Museum listed phonetic pronunciations in his Chemical Index of the Minerals. *But he was simply indicating how Britishers say the names; there was widespread disapproval of his proposals in other countries.*

As things stand, the only authoritative sources for "correct" mineral pronunciations are the authors of the original descriptions of each new species. Unfortunately, very few of these authors have taken the opportunity to establish official pronunciations by writing them into the formal published descriptions of new species.

As for szenicsite, I have been informed by Dr. Carl Francis (author of the abstract on szenicsite in vol. 25, no. 1, and of the future formal description) that he will cite "zeniksite" as the official pronunciation when the formal description is published. *Ed.*

HUMOROUS ADS

The controversy over the Conklin advertisement and the review of past efforts were *most* amusing. Really, isn't all advertising pretentious to some degree? Mercifully, your advertisers don't layer their pretensions with the pedanticism some curators and academics display in their sermons to the unwashed readership.

Best regards to the *Mineralogical Record*, Larry Conklin, and all your advertisers and contributors who don't take themselves too seriously.

Bob Turner
N. Yorkshire, England

COLLECTION STOLEN

A valuable 19th-century collection of natural crystals was stolen recently from the Moscow Agricultural Academy's Geological Museum. The collection includes 177 specimens, and was assembled by the famous Russian mineralogist and crystallographer Evgraf Stepanovich Fedorov (1853–1919). The thieves also took Fedorov's crystallographic and petrographic instruments, including the prototype models of the universal stage (made in Germany according to Fedorov's designs). Finally, a 35-kg (70-pound) iron meteorite, possibly Gibeon, collected in the 19th century, was also taken. The thieves may attempt to sell the stolen items on the Western market. Please let us know if any information turns up.

Dr. M. A. Nazarov
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Geochemistry and
Analytical Chemistry
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Moscow 117975 Russia

MICROMOUNT CREDITS

It has been drawn to my attention that there are some errors in attribution in the color photo section of Quintin Wight's book, *The Complete Book of Micromounting*. The following photographs, originally printed in the *Mineralogical Record* of July/August, 1991, in the article "The Kalahari Manganese Field: An Update," and attributed to Martin Kohler, were actually taken by Dr. Ludi von Bezing, and represent specimens in Dr. von Bezing's collection:

Page 247: Bultfonteinite
Page 254: Inesite
Page 257: Manganite
Page 268: Sugilite

The color photos and captions were compiled by the editor (not the author). We regret any vexation which this misattribution may have caused. Ed.

Widgiemooltha *(continued from p. 291)*

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Microminerals

by **Bill Henderson**

Letters from Readers

After the column describing some of my mounting and filing methods (vol. 23, no. 5, p. 420), I received several letters from readers describing their own techniques. Ole Ljostad, of Elverum, Norway, is an advanced collector with fine material from a number of nepheline syenites and similar rocks. He writes that, on returning from field collecting, he routinely checks all his material with an ultraviolet light as well as under the microscope. Collectors of microminerals from Mont Saint-Hilaire and other nepheline syenite localities would well agree with him—many species are best spotted or even tentatively identified by the presence or absence of fluorescence and its color. He also sends good advice about using an ultrasonic cleaner, a tool just about essential for cleaning microcrystalline material. Many collectors do not know that the tiny air bubbles liberated in an ultrasonic cleaning bath can adhere to the specimen, and interfere with the cleaning action. Ole uses boiled water, from which most of the dissolved air which forms the bubbles has been removed. He then simply rinses the specimens. I rinse them first with tap water, and then with "distilled" water from my dehumidifier; tap water, on drying, can leave a thin film of dissolved salts on crystal faces.

Ole is very concerned about the archival quality of micromounts, and the information contained in the specimen itself. In particular, he worries that adhesive labels will eventually fall off. I have found from personal experience that they are sometimes attacked by mold to the point where they become illegible. Further, perhaps one out of 50 of my photo-reduced labels stuck on with rubber cement *does* fall off after a very short time (because the cement was too dry when the label was applied). They can be re-attached, but I don't really know for how long. To circumvent this, Ole writes his labels directly on his polystyrene boxes with ink which etches the box surface, and thus will never come off. Further, such labels are much less susceptible to mildew. In addition, he uses a fairly large box, as do many Europeans. He does so in order to retain more matrix with its paragenetic information than is possible with the smaller American boxes. I might mention that many advanced American collectors are making "micromounts" in boxes 2 x 3 inches in size and larger. No important specimen should be cut down to the point where information as to associated species, etc., is lost; nor should large specimens be trimmed to fit a box if the esthetics of the specimen are destroyed or diminished. The box should fit the specimen, not vice versa.

Glen Pryor, of Grand Junction, Colorado, writes that he pre-cuts balsa wood supports for his micromounts to various sizes using a small, homemade miter box and a "razor" saw, obtainable at craft supply shops. He then throws a large number of them into a jar partially filled with India ink, which he buys in quantity. He shakes it and lets it stand. After separating the stands and letting them dry on paper towels, he has a quantity of stands with a matte, black finish at a fraction of the effort of painting them individually.

Jack Donahue (Santa Cruz, California) may have solved several problems with photo-reduced labels, including my bad cases of label rot. He applies his labels as I do, but then sprays them with matte-finish artist's fixative. This prevents smudging, allows cleaning, and will probably retard fungus. He uses *Blair Spray Fix* workable matte fix #125.

A letter from Ted Hadley, of Sunnyvale, California, was a mixture of high and primitive tech. He, like so many others today, has entered information on his micromineral collection into a computer database. He can enter the first few letters of a mineral name, press (Enter), and immediately recover catalog numbers, locations, associated minerals, formulas, dates of acquisition, sources, and much else. More mundane, he writes that he mounts small crystals on cats' whiskers, and larger ones on basswood. The latter he finds not as rough or splintery as the usual balsa. It is, of course, harder to cut.

I assume that by now, most collectors of microminerals have read Quintin Wight's excellent book on micromounting. I highly recommend it to those who have not. I do disagree with him on a couple of points which follow.

In his introduction, Quintin gives Neal Yedlin's definition of a micromount, to which both he and I subscribe. That is, that a micromount is "a natural mineral specimen, preferably in distinct crystals, mounted, properly labeled, and requiring magnification for meaningful observation." Quintin goes on to expand upon this definition, and there I cannot agree with all he says. He maintains, as did Neal, that "mounted" means *permanently* mounted. Further, he denigrates attaching specimens to the box using "sticky stuff," and refers to the practice as packaging, not mounting. Well, what is permanence? I have many times seen specimens mounted with rigid, brittle glue snap loose to rattle around in their boxes. I have seen specimens on friable matrices such as soft and porous goethite break loose, leaving a thin layer of matrix on the glue. I have seen specimens with "awkward" bottom shapes tottering crazily on rigid supports and glue layers. I have seen rigid glues "lift" black paint from plastic boxes, again leaving the specimen and base loose. Microminerals sent through the mail on rigid supports will break loose far more often than those on sticky stuff. In short, it is a real question whether Quintin's rigid glues or sticky stuffs are more permanent. In many cases, the above problems are solved using that abhorred sticky stuff, and the sticky stuff is more permanent. Further, although glassy materials such as *Mortite* insulating putty or *Blue-Tac* reusable adhesive putty (sticky stuffs) can flow with time, chances are they will not do so to a noticeable extent when supporting light objects such as micromounts. Also, they harden with time. Such non-rigid adhesives then have several advantages: (1) they deform to fit the bottom of micromineral specimens, (2) mounting specimens proceeds much faster than with rigid mounts, (3) the orientation of specimens can be corrected after mounting, and (4) most important of all, specimens can be removed far more easily at a later date in order to photograph, test, or more intensively study the minerals present.

Quintin refers also to an aesthetic touch which he says separates micromounting from collecting specimens in small boxes. So he may. However, I think any micromounter is free to mount his specimens either "permanently" or on sticky stuff. I even box a few crystals loose so they can be removed for photographing, rotated, lent for study, etc. Certainly, I mount specimens for their protection far more than for "aesthetics," and how I mount a particular specimen depends on the use for which it is intended.

Finally, a belated correction to a previous column. Two writers (J. Michael Howard, of the Arkansas Geological Commission, and Mary Ann Burtner, of Flippin, Arkansas) sent me letters pointing out that the bright yellow bow ties of "calcite" from the Monte Cristo mine in Arkansas in Figures 11 and 12 of my *Microminerals* column in the March-April 1989 issue of the *Mineralogical Record* are misidentified. In fact, they are well known to local collectors to be smithsonite. Subsequent microprobe analysis of my specimens showed major Zn and trace Ca. Hence, they are indeed correct.

This is, I am quite sure, the first column I have written which contains no photos or sketches of any kind (except of me). I'll make up the deficiency in future columns.

Wm. A. Henderson, Jr.
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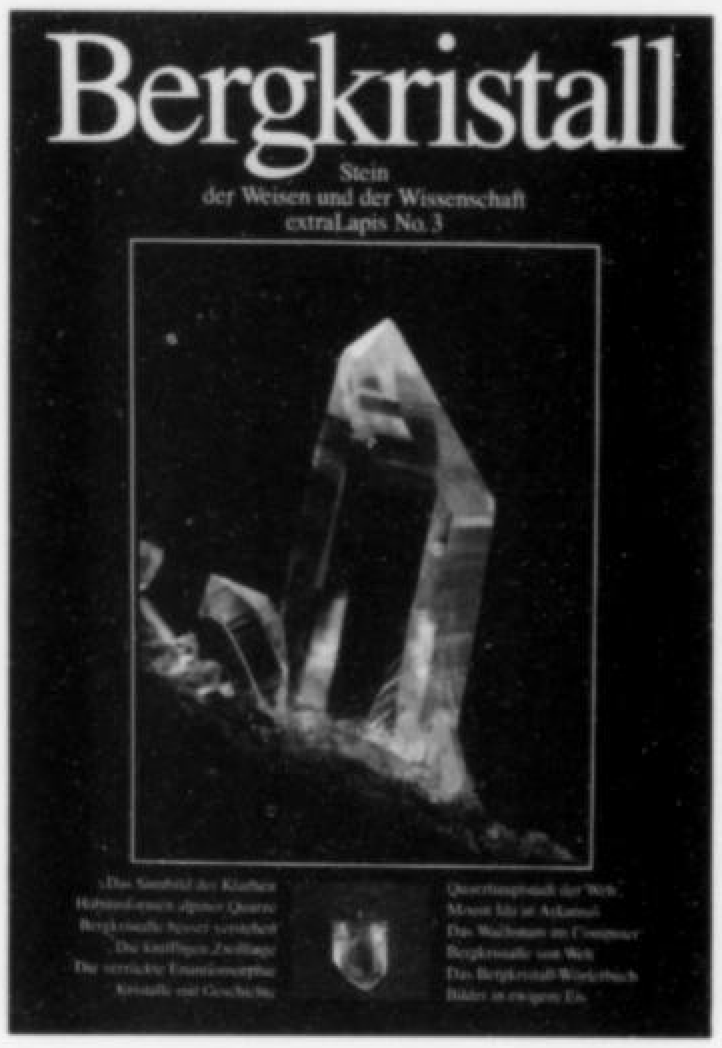

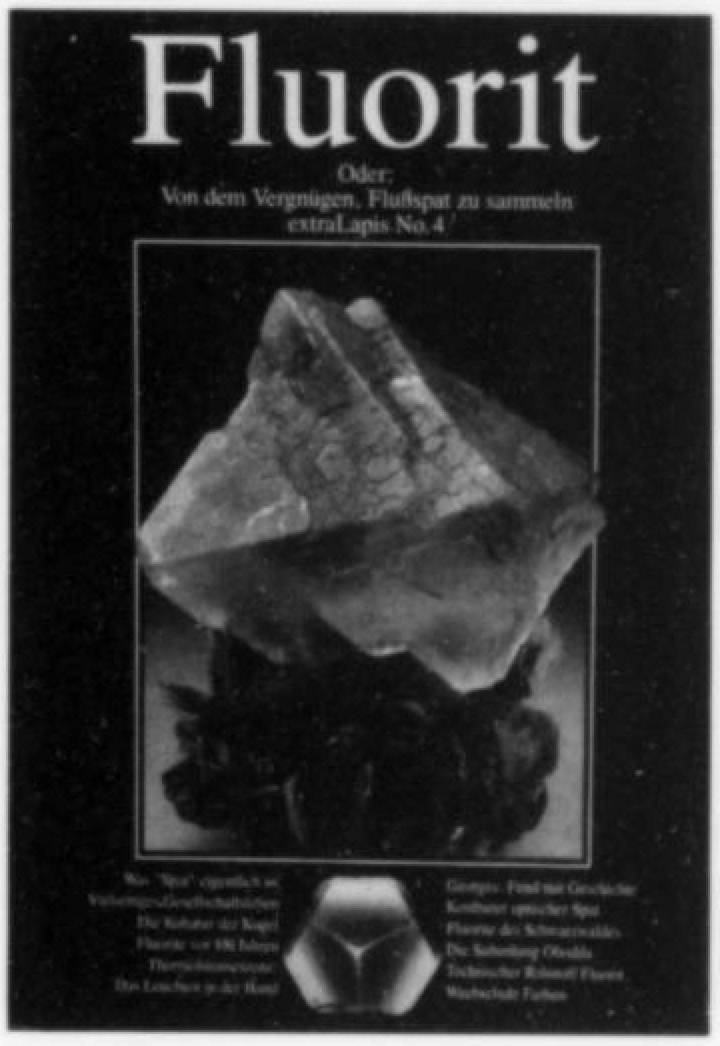

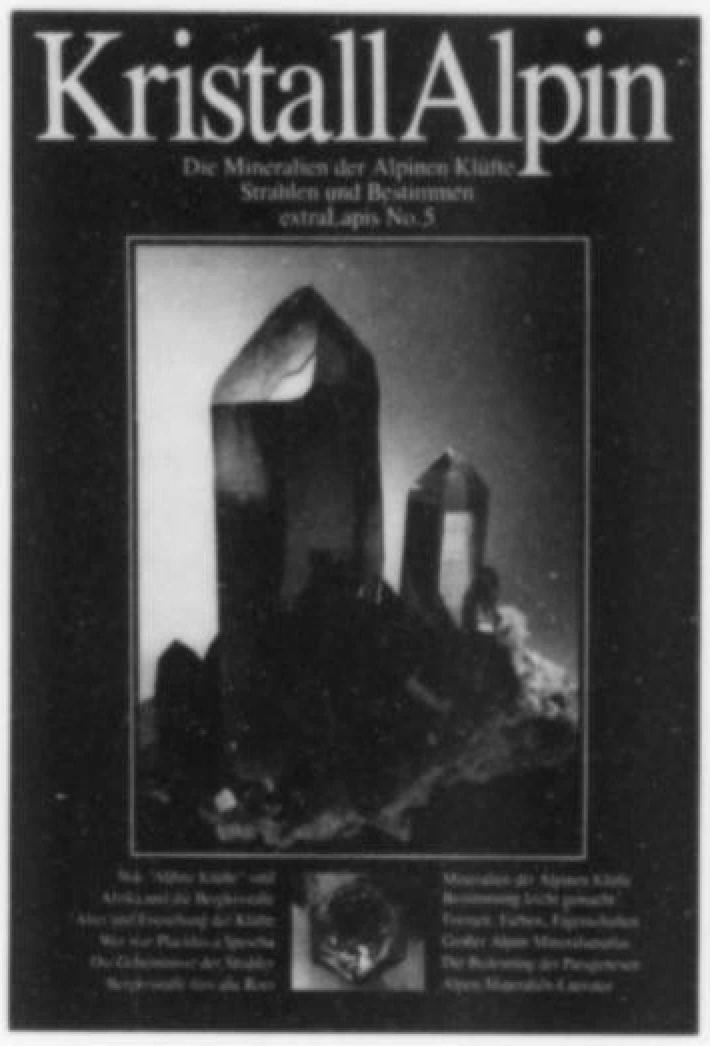

Bergkristall
(ExtraLapis No. 3, 1992)
Fluorit
(ExtraLapis No. 4, 1993)
Kristall Alpin
(ExtraLapis No. 5, 1993)

Published by Christian Weise Verlag, Orleansstrasse 69, D-81667 Munich, Germany; softcover, 21 x 29.5 cm, 96 pages each; ISBN #3-921656-257, 3-921656-27-3, and 3-921656-28-1 respectively; price: DM 29.80 each. (in German)

Christian Weise, publisher of *Lapis* magazine, and his editor Max Glas have been producing a series of special issues not included in a regular *Lapis* subscription (hence their designation as *extraLapis* issues). The first and second issues focused on gold and emerald, respectively. These three subsequent issues deal with (3) quartz (the colorless crystalline variety only), (4) fluorite, and (5) Alpine quartz varieties found in the Alps (including smoky quartz, gwindels and amethyst, and a variety of associated species: feldspars, fluorite, carbonates, brookite, rutile, anatase, titanite, apatite, epidote, piemontite, zoisite, clinozoisite, and many others). Each issue is the product of a number of authors and photographers, and is chapterized in a logical manner, covering history, geology, minerals, special collections, and other aspects of interest to the collector. The specimens pictured are generally superb, and the color photography and printing are impeccable. These are superb examples of the publisher's art, produced on higher-quality stock than *Lapis,* are are enjoyable even to those without a reading knowledge of German. Highly recommended.

W.E.W.

Phosphate Minerals of Victoria

by W. D. Birch and D. A. Henry. Published (1993) by the Mineralogical Society of Victoria as Special Publication No. 3; P.O. Box 12162, A'Beckett Street, Melbourne, Victoria 3000, Australia; softcover, 17 x 24.5 cm, 184 pages, ISBN #0-9594573-2-1, $64 (Australian dollars; airmail postage included).

This third book in the series of Special Publications issued by the Mineralogical Society of Victoria maintains their high level of quality in content, illustrations and production values. The eight chapters are divided according to geological environment, giving good descriptions of many important localities in each chapter. The abundant color photographs of specimens by Frank Coffa are all excellent. Highly recommended.

W.E.W.

Mineralogie der Grube Lengenbach, Binntal, Wallis

by B. Hofmann, S. Graeser, T. Imhof, V. Sicher and H. A. Stalder. Published (1993) as Jahrbuch des Naturhistorischen Museums, Bern, *Band* **11**, *90 pages; softbound, 23 x 16 cm, illustrated in black-and-white and color, ISBN #3-907-088-04-2; price: 20 Sw.fr.*

Lengenbach is celebrated for its lead-arsenic sulfosalts and has provided mineral specimens and topics for research for more than 200 years. Today the quarry is worked solely for specimens by the Arbeitsgemeinschaft Lengenbach. This short guide contains a complete descriptive list of species, both from Lengenbach and from the nearby area of Turtschi. New species described include baumhauerite-2a, edenharterite, erniggliite and stalderite, and full description of them are given. Topographical maps and cross-sections of the Lengenbach quarry depict the development of its workings from 1961 to 1992 and also show the mineral zoning. There is a short account of the methods of specimen recovery and statistics on the minerals found during the period from 1958 to 1992. A bibliography lists the papers published on Lengenbach-related subjects since 1978.

This is a very useful and well-produced book (forming a single issue of the journal cited above); the color photographs are excellent, some of them illustrating newly described species.

Michael O'Donoghue

Mineralien richtig reinigen

("Minerals Properly Cleaned") by Ernst Sury. Published (1991) by Sektion Basel S.V.S.M., second edition, softcover, ring-bound, 60 pages; price: 18 DM.

This is a useful book in the form of tables showing the best way to clean mineral specimens. Minerals are listed in alphabetical order and various cleaning agents are listed with them. These include several different acids and ultrasonic cleaners. It is a useful preliminary guide, but collectors need to know much more detail before starting any cleaning process on their specimens.

M.O'D.

Eifel Mineralen, Mineraux, Mineralien

by Eddy Van Der Meesche. Published by Mineralcolor vzx, Gent, Belgium. Softcover, 126 p., illustrated in color with 1 map. ISBN #90-74669-01-8, price: 33 DM.

This is a photo-essay depicting 50 or so minerals from the German Eifel in sizes averaging 5 mm. The text is quite short and in Flemish, French and German, but the quality of the photographs is high and successfully depicts attractive and interesting crystal forms. Those with an interest in this mineralogically important region should certainly buy the book.

M.O'D.

Jade, Juwel des Himmels

("Jade, Jewel of the Heavens") Published (1993) by Christian Weise Verlag, Munich; 28 pages, softcover, illustrated in color.

This is a short but informative and well-illustrated catalogue of an exhibition held in Munich during 1992 under the title *Jade aus der Qing-Dynastie, 1644–1911*. Many of the objects are illustrated in color and all have descriptions which include dimensions. Brief notes on jadeite and nephrite precede the descriptive section.

M.O'D.

MINERAL STORIES

Lawrence H. Conklin

Collecting in the Lion's Mouth

John A. Powloski

About 25 years ago I went to collect quartz at the Ace of Diamonds site in Herkimer, New York. After working down the face of a ledge for two days, I finally punched a hole into a large vug. The pocket was awkwardly situated at floor-level, and there was little room to maneuver between the rock face and the tailings; nor could I get in position to actually see inside the pocket.

For two hours I labored against the hard rock to enlarge the small opening I had made. Finally it was big enough for me to reach way back in and feel around. Almost immediately my hand came across a fist-size crystal! Working feverishly to free the unseen beauty deep in the cavity, my arm became increasingly abraded against the rough inner surface of the narrow channel into the pocket. It began to swell up from the scratches and bruises, to the point that I could not remove my arm from the hole! I was stuck. Talk about being caught with your hand in the cookie jar.

For what seemed like an eternity (probably about half an hour) I laid on my back in the hot July sun, hoping the swelling would go down enough for me to extricate my arm. At last I pulled free. But did I learn my lesson? No! I went right back to work trying to get that beautiful crystal out. And before long my arm swelled up and I was trapped a *second* time. That finally taught me to be more cautious. But it was worth all the time and aggravation . . . I did get the crystal.

A Good Deal

Art Smith

In July of 1978 I was just beginning a Colorado vacation with my family and was heading north through the mining town of Creede on the eastern edge of the San Juan Mountains. It had been a few years since my last visit and I was anxious to see how the collecting was. On the north edge of town along Willow Creek I noticed that Al Birdsey, an ex-miner, still had his mineral sign out, but I wanted to do my own collecting first at the Commodore No. 5 mine dumps a short distance up the west branch of Willow Creek. I had always been quite successful in these dumps before, and there was a constant resupply of material from the mines above. However, this time things were different. Emperius had shut down their operations at the Commodore mine, and the dumps had all been well picked over and were essentially barren.

In somewhat of a panic I went back to Al Birdsey's to see what he might have. I knew from observing on the way into town that the Homestake Mining Company's operation on Bull Dog Mountain was still going, and Al might possibly have some native silver or other minerals from this mine, but I was partial to the mines of the Amethyst and associated veins on West Willow Creek.

I was greeted cordially and shown some polybasite and acanthite in barite from the Bull Dog that would make nice micromounts so I bought three or four large pieces. I mentioned how sad I was to see that Emperius had shut down, and that I would sure like to get some of their material. With barely a word Al led me out the back door to a small room in a shed. It was lined with shelves, five or six high, and all were loaded with large and small specimens that were straight from the Commodore mine. Trouble was they had not even been washed, and most were somewhat covered with dried mine muck. Still, I could see round bulges of sphalerite crystals and tinges of purple amethyst; my spirits soared! This bonanza might be my last chance of obtaining specimens from the Commodore, which might never reopen. Al left me to do my own choosing and went back into the house. I went through the material specimen by specimen, and anything that looked good through the muck I gently stacked in the middle of the wooden floor. An hour plus flew by and I had accumulated a pile several feet in diameter and over 2 feet high. Wife and child were waiting by the truck out front, so there was no time to highgrade. I knocked on the door and told Al that I would take everything stacked on the floor. He said it would take a while to figure out what it might cost.

"That's OK; I'll be around town and will pick them up in a couple of days," I said, and headed to the truck.

It was not until I was pulling away in the truck that it hit me. "Man, you went overboard!" I thought. "You probably have $600 or more of specimens stacked on the floor." In those days, $15 was an expensive specimen to me. We were just starting a two-week vacation and a $600 outlay on rocks would mean we had better head back home to Texas pronto because our money would be gone.

My next two days of mineral collecting and fishing were pure mental torture. I did not share with the family what I had done, and there seemed no alternative but to back out of the deal; but I wanted those specimens. I put off going back to Al's until we were ready to leave town. Time finally ran out, and it was time to face up. I fearfully walked up to the door and knocked. Al opened the door and welcomed me like a long lost friend. That really scared me. "He plans to live happily everafter on what he gets from me," I thought.

"Sit down and relax. Want a drink or something?" He said.

I grew more fearful, but managed to make some small talk for a bit. Finally the anticipated bombshell could not be avoided.

"What do I owe you for the rocks I picked out?"

Al grew quiet, then led me out to the shed where the specimens were all neatly wrapped and boxed.

"Well . . . I will have to have $40 for the lot," he said.

I whipped out a couple of twenties and quickly loaded the truck to keep the dream going. The rest of the vacation trip was a relief, and I now remember none of it. When I got home and unwrapped the specimens, the dried muck was *still on* them; he had not rinsed them off to see what they were like before pricing them. When they were cleaned, several of the specimens each proved to be worth more than the $40 I paid for the whole lot. Nevertheless, I'm sure that Al was as happy to get rid of them for the $40 as I was to get them.

Serendipity

John Marshall

My interest in collecting minerals began at the age of 13. Around that time my mother took me with her to visit a lady-friend who had a small collection of minerals. I will never forget being bug-eyed with excitement at seeing such fascinating rocks as a two-carat diamond crystal sitting on its matrix of kimberlite. The visit concluded with this kind lady presenting me with a half-dozen of her specimens (although none had labels). One was a very nice emerald crystal section that measured 3 cm long. Naturally my interest in minerals blossomed.

One day, 35 years later, while looking at my specimens, I recalled that old collection, and decided to write to the lady to see if she still had them and if they might be for sale. Indeed they *were* for sale, because the lady was moving to a rest home and there was no room for her cabinet. I purchased most of the collection, including the diamond on matrix and a loose emerald crystal. Imagine my surprise when, finally at home, I found that the new emerald crystal fit perfectly on the old crystal section that I had gotten so many years before. Now I have an emerald crystal that measures 7 cm long! The opinion of Dr. Carl Francis of the Harvard Mineralogical Museum, based in part on the discovery of a small rutile crystal on the new part, is that the emerald is from Hiddenite, North Carolina.

Serendipity II

Pete J. Dunn

There was a period in the 1980's when I had research underway for many new mineral descriptions. Analytical data for these projects were sorted into bins in my office, one bin for each potential new species under investigation.

One new mineral I was studying was a dark red calcium-manganese arsenate from Sterling Hill, New Jersey. The material had been found in 1974 and was subsequently preserved by John L. Baum, who called it to my attention. Unfortunately, although I had obtained a microprobe analysis and an X-ray powder pattern, there just wasn't enough good material to yield a thorough, reliable description. Sadly, it appeared as though this potential new mineral might never become fully known.

One day I spent a while studying the X-ray powder data (which shows something of the crystal structure of a mineral) for this apparently lost cause; I then put the data back in its bin. Later that day I decided to spend some time working on another new species, a bright yellow calcium-manganese silicate, specimens of which had been found at the Taylor mine in Franklin, New Jersey, in 1874 and preserved later at the Smithsonian Institution and at Harvard University. For this mineral, unlike the other, I had enough to work with. I reached for the powder data in its bin and looked it over. Immediately, I thought there was a problem: this data looked like the data for the too-sparse Sterling Hill arsenate I had examined that morning. I assumed I had put them in the wrong bin earlier by error, but, no, that data was indeed still in the proper bin. With much excitement I held the two X-ray films side-by-side; they were nearly identical! A breakthrough!

It became evident by sheer coincidence that these two new minerals with such different appearance and chemical composition had the same crystal structure! Found by collectors a century apart, the specimens had eventually found their way from hand-to-hand, collection-to-collection, across several states, and into a single laboratory, where they rested simultaneously in their isolated, respective bins only two feet from each other until a bleary-eyed mineralogist recognized them as secret brothers, both unknown to science.

The end result was that, as an isostructural analog of the more abundant Ca-Mn silicate, the sparse red Ca-Mn arsenate could be more thoroughly characterized by analogy. Both became new species at the same time and were described together, one each from the sister deposits of Franklin and Sterling Hill. The red Sterling Hill arsenate was named *wallkilldellite* after the beautiful Wallkill River valley (dell) which drains both zinc deposits. The yellow Ca-Mn silicate, which made wallkilldellite's characterization possible, was named *kittatinnyite* after a local Indian word meaning "endless hills," in allusion to the topography of the Franklin–Sterling Hill area. These minerals were the first natural silicate/arsenates with layered structures.*

All in all, it was a delightful experience!

It's a Small World

L. H. Conklin

This story took place back in the early 1960's when Frederick Ludlow (Rick) Smith, III and Charles Locke (Charlie) Key were partners in Short Hills, New Jersey. They dealt in mineral specimens under the name of *New Jersey Mineral Supply*. As a major part of their operation they traveled all over the world; some of their favorite hunting-grounds were the remote parts of South Africa. (I particularly recall a superb *orange-colored* beryl crystal, about 10 x 15 cm, that Rick once showed me. It had been retrieved from some exotic area near the Namib Desert.) On one occasion, as Rick later related to me, they spent many gruelling days tracking down a hermit-like person who lived in "the South African bush," and who was rumored to have many fine minerals he might be willing to sell.

As soon as they entered his house and saw what lay all around them they forgot about the previous hardships. Here were fine specimens. Surely, because of his remoteness, the owner could not know the retail value of his holdings, and Rick and Charlie would certainly be able to get a "good buy."

After many queries about prices, and just as many unsatisfactory replies, one of the hopeful buyers told the owner that the prices he was asking for his specimens were too high, and that the pieces were simply not worth what he asked. The answer was something that amounted to—"is that really so?," whereupon the gentleman reached up to a shelf and produced a series of "Lawrence H. Conklin, 31 West 47th St., New York, New York—Fine Minerals Price Lists" and proceeded to make his point.

It is my recollection that Rick and Charlie still managed to get what they wanted, although perhaps at a price a bit higher than they wanted to spend. *I*, however, was not returned to their "good list" for quite a while.

Reversals of Rarity

L. H. Conklin

Georg F. Kunz, the prominent turn-of-the-century gemologist and mineral dealer to the upper class, is the subject of many anecdotes in the lore of collecting. One such involves a fine amethyst specimen which, through his association with Tiffany's in New York, was part of their display at the Panama-Pacific Exposition in San Francisco in 1915. Shortly thereafter, Kunz sold the piece, labeled as having come from Uruguay, to William Boyce Thompson, the founder of Newmont Mining Company.

I acquired this specimen for my own collection in 1975, primarily because of its historical connection with those notable men. But I've held onto it all these years for an entirely different reason. (Incidentally, I ultimately gave up collecting amethyst, partly because too many specimens were being offered with falsified localities. The last straw was a Pohndorf mine specimen from Montana that was labeled as being Siberian.) The reason I've kept the Kunz/Thompson amethyst is that, despite its label, it is not from anywhere near Uruguay, but rather from Delaware County, Pennsylvania. It shows a weak lower termination, making it doubly terminated (a feature unknown among Uruguayan amethysts, as far as I know), and has the "hourglass" color zoning pattern typical of Pennsylvania specimens.

Why would someone falsify a locality in a way that renders the specimen *less* rare and less valuable? Surely a fine Pennsylvania amethyst would hold more interest than one of the countless Uruguayan specimens that have for decades flooded the world market.

The answer is quite simple. According to the accounts of amethyst collecting in Pennsylvania during the early years of this century, specimens such as the Kunz/Thompson example were being found by the bucketful. In 1915, Uruguayan specimens were still an exotic curiosity. (Thompson did acquire large, legitimately Uruguayan amethysts, but not until the 1920's.) Kunz's knowledge of mineral localities was unequalled in his day, and it seems unlikely that he himself could have been fooled by his supplier. He must bear responsibility for the false information, and he surely obtained a *higher* price from Thompson as a result of the mislabeling.

I once acquired another mislabeled Kunz/Thompson specimen from the American Museum of Natural History. It is a slender, pale green emerald crystal labeled as having come from "Brazil," then an exotic source, but it is, in fact, from much closer to (Kunz's) home: North

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*Formerly the only known example of a natural isostructural silicate/arsenate pair of minerals was berzeliite/manganberzeliite, with garnet-like structure.

Carolina. Once again, the abundance of North Carolina emeralds in Kunz's day has not persisted to the present time, and the relative rarity of the two localities has now been reversed.

(Thanks to Joseph Peters, William Zeek and Robert Curran for information.)

The Insurance Appraiser

L. H. Conklin

Back in the late 1950's or early 60's I thought it was a responsible act to insure my inventory of rare and valuable minerals. At that time I had a very sharp New York City insurance broker who really knew his way around the business, and I presented him with my request. In almost no time at all he had a quote from an underwriter for so many dollars per thousand which, after some thought on my part, seemed much too low. An inquiry to my broker brought a similar response, and the promise to find out why the quote was so low (but hopefully without getting it raised in the process). He called back shortly afterward and told me that the rate quoted was indeed correct. The underwriter's reply to his query, he said, was: "Who would steal *that* shit?"

Ed. note: We normally would not use that last word in the *Mineralogical Record,* but in this case, as an *official insurance underwriter's assessment,* it seemed essential to the story.

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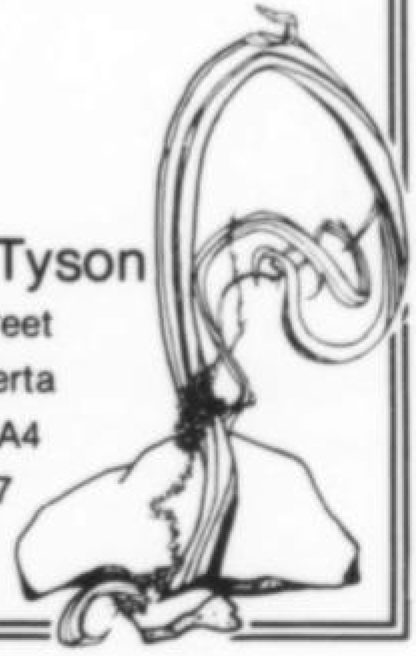

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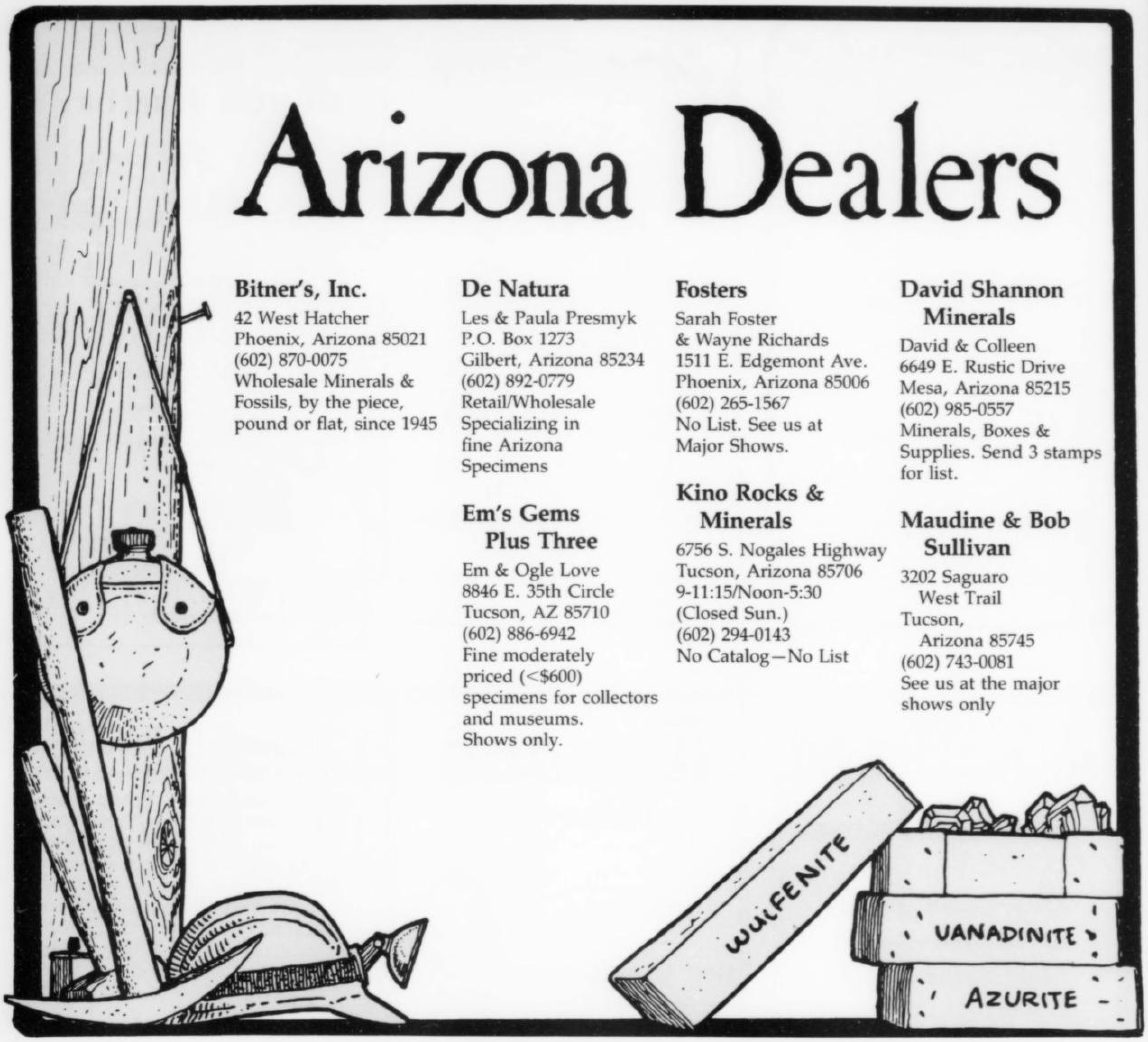

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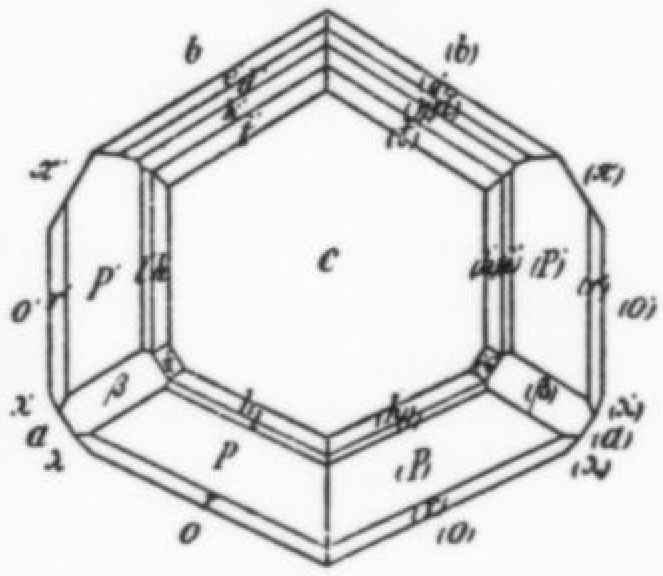

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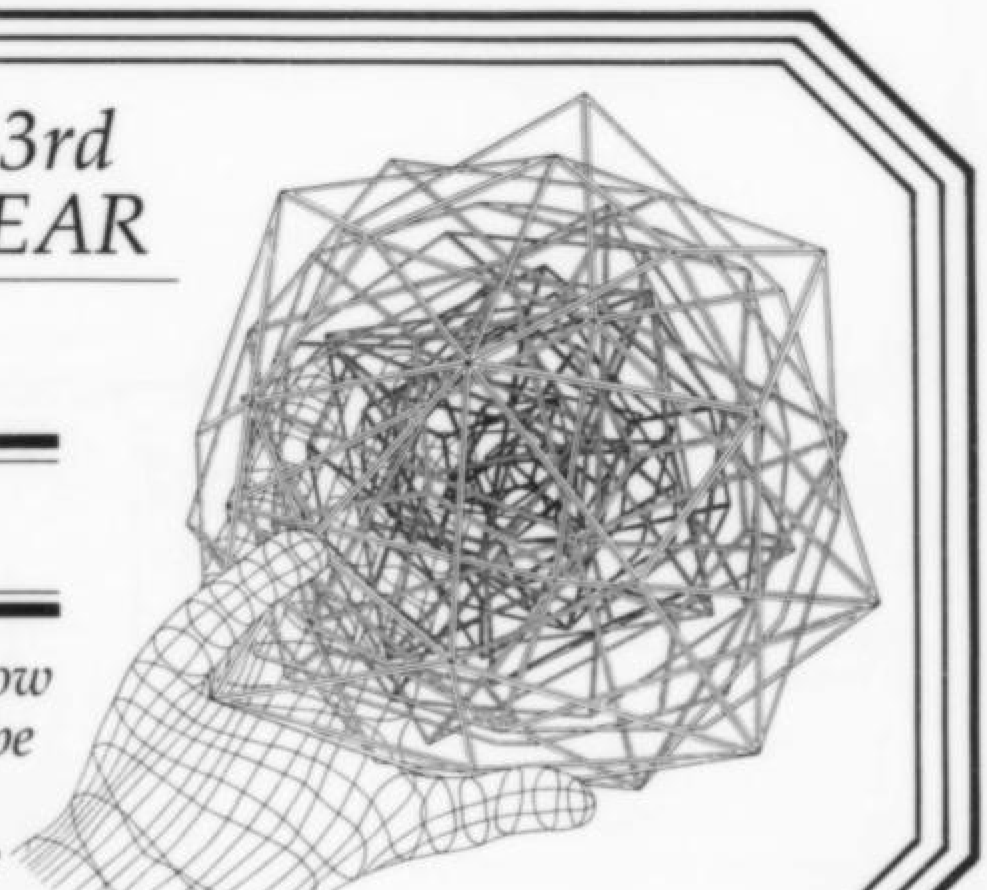

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International Mineralogical Association

The information given here is provided by the Commission on New Minerals and Mineral Names, I. M. A. for comparative purposes and as a service to mineralogists working on new species.

Each mineral is described in the following format:

Chemical Formula
IMA No. (any relationship to other minerals)
Crystal system, space group
unit cell parameters
Color; luster; diaphaneity.
Optical properties.
Strongest lines in the X-ray powder diffraction pattern.

The names of these approved species are considered confidential information until the authors have published their descriptions or released information themselves.

NO OTHER INFORMATION WILL BE RELEASED BY THE COMMISSION.

J. A. Mandarino, Chairman
Commission on New Minerals and Mineral Names
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1992 PROPOSALS

$FeZr(PO_4)_2\cdot 4H_2O$

IMA No. 92-001
Monoclinic: $P2_1/c$
a 9.12 b 5.42 c 19.17 Å β 94.8°
Pale yellowish white; vitreous to dull; transparent.
Biaxial (+), α 1.644, β 1.652, γ 1.652, 2V(meas.) 0°, 2V(calc.) 0°.
9.58 (75), 4.572 (65), 4.382 (80), 4.092 (60), 3.160 (100), 2.640 (70).

$Bi_2O(OH)_2SO_4$

IMA No. 92-002
Monoclinic: $P2_1/c$
a 7.700 b 13.839 c 5.686 Å β 109.11°
Colorless; adamantine; transparent.
Biaxial, indices of refraction calculated from reflectance data at 589nm: R_1 1.91, R_2 1.99. 3.644 (60), 3.466 (60), 3.206 (100), 2.924 (70), 2.782 (50), 1.984 (90).

Sb_2Se_3

IMA No. 92-003 The selenium analog of stibnite.
Orthorhombic: Pbnm
a 11.593 b 11.747 c 3.984 E
Black; metallic; opaque.
In reflected light: white, distinct anisotropism, distinct bireflectance, pleochroic white to grayish white. $R_{max.}$ & $R_{min.}$: (42.62, 40.55%) 470nm, (41.95, 39.02 %)546nm, (41.23, 39.42 %)589nm, (44.39, 41.56 %)650nm.
3.70 (70), 3.17 (50), 2.870 (100), 2.625 (60), 1.930 (30), 1.764 (35).

$Mg[UO_2(AsO_3)_x(AsO_4)_{1-x}]_2\cdot 7H_2O$ x about 2/3

IMA No. 92-005
Monoclinic: C2/m
a 18.194 b 7.071 c 6.670 Å β 99.70°
Bright yellow to straw-yellow; vitreous; transparent.
Biaxial (-), α 1.610, β 1.730, γ 1.740, 2V(meas.) 34°, 2V(calc.) 30°.
9.02 (100), 4.90 (40), 4.48 (80), 4.00 (40), 3.53 (40), 3.28 (50), 3.01 (60), 2.849 (60).

$Ni_5(CO_3)_4(OH)_2\cdot 4{-}5H_2O$

IMA No. 92-006 The nickel-analog of hydromagnesite.
Monoclinic: $P2_1/c$
a 10.06 b 8.75 c 8.32 Å β 114.3°
Bluish green; silky; transparent.
Biaxial (sign unknown), α′ 1.630, γ′ 1.640, 2V unknown.
6.30 (5), 5.75 (10), 4.36 (4), 4.14 (3), 2.871 (4b), 2.458 (2b), 2.120 (3).

$NaH(CO_3)H_3(BO_3)\cdot 2H_2O$

IMA No. 92-008
Monoclinic: C2
a 16.119 b 6.928 c 6.730 Å β 100.46°
Colorless; vitreous; transparent.
Biaxial (-), α 1.351 (calc.), β 1.459, γ 1.486, 2V(meas.) 50°.
6.36 (25), 4.203 (6), 3.464 (100), 3.173 (59), 2.608 (5), 1.731 (19).

$Ca_9B_{26}O_{34}(OH)_{24}Cl_4\cdot 13H_2O$

IMA No. 92-010 A triclinic polymorph of 92-011.
Triclinic: P1
a 12.759 b 13.060 c 9.733 Å α 102.14° β 102.03°

γ 85.68°
Colorless to very pale yellow; vitreous; translucent to transparent.
Biaxial (+), α 1.537, β 1.548, γ 1.570, 2V(meas.) 77°, 2V(calc.) 71°.
9.21 (70), 7.69 (100), 5.74 (60), 4.63 (40), 3.845 (35), 2.199 (30b).

$Ca_9B_{26}O_{34}(OH)_{24}Cl_4\cdot 13H_2O$

IMA No. 92-011 A monoclinic polymorph of 92-010.
Monoclinic: $P2_1$
a 19.88 b 9.715 c 17.551 Å β 114.85°
Colorless to very pale yellow; vitreous; translucent to transparent.
Biaxial (+), α 1.542, β 1.545, γ 1.565, 2V(meas.) 47°, 2V(calc.) 43°.
9.03 (60), 8.56 (100), 6.62 (70), 6.14 (30b), 5.12 (30), 4.09 (30), 3.768 (30), 3.493 (30).

$Ca_2(CaMn)(SiO_3OH)_2(OH)_2$

IMA No. 92-012
Orthorhombic: Pbca
a 9.398 b 9.139 c 10.535 Å
Colorless; vitreous; transparent.
Biaxial (+), α 1.634, β 1.640, γ 1.656, 2V(meas.) 65°, 2V(calc.) 63°.
4.18 (45), 3.231 (100), 2.846 (42), 2.789 (35), 2.391 (42), 2.042 (28).

$Bi_3O(OH)(PO_4)_2$

IMA No. 92-013 The phosphate analog of preisingerite and schumacherite.
Triclinic: P
a 9.798 b 7.250 c 6.866 Å α 88.28° β 115.27° γ 110.70°
White to pale pink, sometimes brown; vitreous; transparent to translucent.
Mean index of refraction estimated from reflectance data: 2.01 at 589nm.
4.437 (46), 3.247 (87), 3.188 (100), 3.135 (95), 3.026 (75), 2.953 (47), 2.165 (41).

$Na_xCa_yCu_z(Mg,Fe^{3+},Al)_3(AsO_4)_3$

x ~ 0.76, y ~ 0.42, z ~ 0.39
IMA No. 92-014
Monoclinic: C2/c
a 11.882 b 12.760 c 6.647 Å β 112.81°
Light blue; vitreous; translucent.
Biaxial (+), α 1.714, β 1.744, γ 1.783, 2V(meas.) 60°, 2V(calc.) 84°.
4.35 (40), 4.06 (50), 3.56 (40), 3053 (40), 3.495 (60), 3.066 (40), 2.744 (140), 2.605 (40).

$(Fe,Al)_2(SO_4)_3$

IMA No. 92-015 The ferric analog of millosevichite.
Hexagonal: R3
a 8.14 c 21.99 Å
White to light brown; dull; transparent.
Uniaxial (sign unknown), n is between 1.555 and 1.625.
5.99 (28), 4.35 (23), 3.56 (100), 2.97 (20), 2.72 (20), 2.64 (11).

$Mn_5(PO_4)_2(OH)_4$

IMA No. 92-016 The phosphate analog of arsenoclasite.
Orthorhombic: $P2_12_12_1$
a 9.097 b 5.693 c 18.00 Å
Pale yellow, yellow, pale burnt orange; adamantine; transparent.
Biaxial (sign unknown), α′ 1.74, γ′ 1.76, 2V unknown.
2.900 (100), 2.853 (70), 2.802 (50), 2.702 (80), 2.022 (15), 1.608 (15).

$Ca_3(Ti,Fe^{2+}Fe^{3+})_2(Si,Fe^{3+})_3O_{12}$

IMA No. 92-017 A member of the garnet group.
Cubic: Ia3d
a 12.162 Å
Black; adamantine; opaque.
Isotropic, ω 1.955.
3.039 (72), 2.720 (100), 2.483 (51), 2.385 (21), 1.973 (24), 1.687 (26), 1.626 (56).

$Ca_2Y(AsO_4)(WO_4)_2$

IMA No. 92-018
Tetragonal: $I4_1/a$
a 5.135 c 33.882 Å
Creamy yellow; vitreous to adamantine; translucent.
Uniaxial (+), ω 1.874, ε 1.918.
4.674 (18), 3.059 (100), 2.571 (19), 1.901 (32), 1.818 (16), 1.674 (17), 1.562 (32).

$C_{14}H_{10}$

IMA No. 92-019
Monoclinic: $P2_1$
a 8.392 b 6.181 c 9.558 Å β 98.48°
Colorless to grayish-white; vitreous to waxy; transparent.
Biaxial (+), $n_{min.}$ 1.75, $n_{max.}$ 1.95, 2V(meas.) 90°.
9.434 (100), 4.941 (11), 4.724 (11), 4.546 (5), 4.028 (13), 3.371 (10).

$(Na,K)(Ca,Na)_2(Mg,Fe^{3+},Fe^{2+})_5Si_8O_{22}(F,OH,O)_2$

IMA No. 92-020 A member of the amphibole group.
Monoclinic: C2/m
a 9.762 b 17.888 c 5.122 Å β 102.25°
Blue green and green; vitreous; transparent.
Biaxial (-), α 1.618, β 1.624, γ 1.627, 2V(meas.) 71°, 2V(calc.) 70°.
9.9 (70), 3.69 (60), 3.34 (100), 3.18 (60), 3.13 (90), 2.82 (70), 1.98 (90), 1.439 (60).

$CuBi_2O_4$

IMA No. 92-024
Tetragonal: P4/ncc
a 8.511 c 5.823 Å
Black; metallic; opaque.
In reflected light: gray, weak anisotropism, weak but distinct bireflectance, pleochroic gray with a faint bluish tint and brownish gray. $R_{max.}$ & $R_{min.}$: (21.1, 19.0 %)482nm, (20.2, 18.0 %)545nm, (19.7, 17.6 %)589nm, (19.5, 17.3 %)659nm.
4.26 (17), 3.191 (100), 2.913 (16), 2.695 (18), 1.947 (18).

$Cu_3TeO_6\cdot H_2O$

IMA No. 92-025
Cubic: P-lattice, space group unknown
a 9.555 Å
Emerald green; adamantine; transparent to translucent.

Isotropic, ω 2.01 calculated from reflectance values at 589nm.
4.26 (40), 2.763 (100), 2.384 (70), 1.873 (40), 1.689 (80), 1.440 (60).

$Mn_4Al_2(OH)_{12}CO_3·3H_2O$

IMA No. 92-026 The *-2H* polytype of 92-027.
Hexagonal: $P6_322$
a 10.985 c 15.10 Å
Orange-brown, pale brown, pale blue, colorless; vitreous; transparent.
Uniaxial (-), ω 1.587, ε 1.547.
7.53 (100), 3.768 (60), 2.578 (50), 2.221 (40), 1.856 (40), 1.552 (40).

$Mn_4Al_2(OH)_{12}CO_3·3H_2O$

IMA No. 92-027 The *-3T* polytype of 92-026.
Hexagonal (trigonal): $P3_112$ or $P3_212$
a 10.985 c 22.63 E
Orange-brown, pale brown; vitreous; transparent.
Uniaxial (-), ω 1.587, ε could not be measured.
7.55 (100), 3.770 (90), 2.670 (70), 2.346 (70), 1.973 (60), 1.586 (30), 1.662 (30).

$Mg_4Al_2(OH)_{12}CO_3·3H_2O$

IMA No. 92-028 The *-2H* polytype of 92-029.
Hexagonal: $P6_322$
a 10.571 c 15.139 Å
Orange-brown, pale brown; vitreous; transparent.
Uniaxial (+), ω 1.533, ε 1.533.
7.63 (100), 3.785 (100), 2.603 (15), 2.496 (15), 2.341 (15), 2.166 (15), 1.991 (15),
1.825 (20), 1.495 (15).

$Mg_4Al_2(OH)_{12}CO_3·3H_2O$

IMA No. 92-029 The *-3T* polytype of 92-028.
Hexagonal (trigonal): $P3_112$ or $P3_212$
a 10.558 c 22.71 Å
Yellow to pale yellow; vitreous; transparent.
Uniaxial (+ or -), ω 1.533, ε 1.533.
7.57 (100), 3.778 (90), 2.570 (40), 2.281 (40), 1.932 (40), 1.524 (20), 1.493 (20).

$Fe_4Al_2(OH)_{12}CO_3·3H_2O$

IMA No. 92-030
Hexagonal (trigonal): $P3_112$ or $P3_212$
a 10.805 c 22.48 Å
Green-brown with black coating; vitreous; transparent.
Uniaxial (-), ω 1.599, ε 1.570.
7.49 (100), 3.746 (50), 2.625 (40), 2.314 (50), 1.948 (40), 1.558 (15), 1.526 (20).

$Na_5YZrSi_6O_{18}·6H_2O$

IMA No. 92-031
Hexagonal (trigonal): R32
a 10.825c 15.809 E
Light green to yellow-green; vitreous; transparent to translucent.
Uniaxial (-), ω 1.585, ε 1.578.
6.03 (32), 5.40 (63), 3.236 (84), 3.127 (88), 3.030 (100), 1.805 (21).

$(K,Na)(Na,Li)_2(Mg,Mn^{3+},Fe^{3+}Li)_5Si_8O_{22}(OH)_2$

IMA No. 92-032 A member of the amphibole group.
Monoclinic: $P2_1/m$
a 9.94 b 17.80 c 5.302 Å β 105.5°
Dark red to brownish lilac; vitreous; transparent.
Biaxial (-), α 1.654, β 1.675 (calculated), γ 1.696, 2V(meas.) 88-92°.
8.890 (M), 8.427 (M), 5.077 (M), 4.442 (M), 3.357 (M), 3.257 (S), 3.132 (S), 2.812 (S), 2.553 (S) plus seven other lines of intensity (M).

$SrMn_2^{3+}[Si_2O_7](OH)_2\ H_2O$

IMA No. 92-033
Orthorhombic: Cmcm
a 6.245 b 9.031 c 13.404 Å
Orange-brown; vitreous; translucent.
Biaxial (+), n's > 1.82, 2V(meas.) 63°.
4.804 (86), 3.373 (66), 2.833 (100), 2.807 (82), 2.695 (98), 2.401 (68).

$\square(Fe_2^{2+}Al)Al_6Si_6O_{18}(BO_3)_3(OH)_4$

IMA No. 92-034 A member of the tourmaline group.
Hexagonal (trigonal): R3m
a 15.967 c 7.126 Å
Bluish black; vitreous; transparent.
Uniaxial (-), ω 1.664, ε 1.642.
6.338 (84), 4.212 (48), 3.989 (38), 3.452 (91), 2.944 (71), 2.573 (100).

$(Mg,Li,Fe,\square)_4Al_{18}Si_8O_{44}(OH)_4$

IMA No. 92-035 The magnesium-analog of staurolite.
Monoclinic: C2/m
a 7.872 b 16.55 c 5.634 Å β 90.00°
Colorless in thin section; vitreous to resinous; transparent.
Biaxial (sign unknown), mean n 1.709, 2V unknown.
4.139 (24), 2.678 (38), 2.390 (50), 2.370 (33), 2.356 (24), 1.968 (100).

$(Zn,Li,Fe,Mg,\square)_4Al_{18}Si_8O_{44}(OH)_4$

IMA No. 92-036 The zinc-analog of staurolite.
Monoclinic: C2/m
a 7.853 b 16.54 c 5.639 Å β 90.00°
Colorless in thin section; vitreous to resinous; transparent.
Biaxial (sign unknown), α 1.722, β unknown, γ 1.734, 2V unknown.
3.001 (61), 2.678 (70), 2.390 (87), 2.363 (46), 2.349 (45), 1.968 (61), 1.964 (48),
1.391 (100).

$NaPbCu_5(AsO_4)_4Cl·5H_2O$

IMA No. 92-037 The tetragonal, lead-analog of lavendulan.
Tetragonal: $P4_122$ or $P4_322$
a 10.066 c 39.39 Å
Intense blue; vitreous; translucent.
Uniaxial (-), ω 1.770, ε 1.710.
9.83 (100), 4.925 (60), 4.482 (50), 3.132 (90), 2.772 (40), 2.515 (50), 1.778 (40).

$Cu_{20}(Fe,Cu,Zn)_6Mo_2Ge_6S_{32}$

IMA No. 92-038
Cubic: space group unknown
a 10.64 Å
Megascopic color unknown; metallic; opaque.
In reflected light: pale yellow to grayish yellow, no anisotropism, no bireflectance, nonpleochroic. R: (23.7 %)470nm, (25.5 %) 546nm, (25.7 %)589nm, (25.6 %)650nm.
3.07 (10), 2.66 (2), 1.884 (8), 1.603 (4), 1.536 ( ), 1.331 (1), 1.220 (2), 1.190(1).

$Cu_{20}(Fe,Zn,Cu)_6W_2Ge_6S_{32}$

IMA No. 92-039
Cubic: space group unknown
a 10.675 Å
Megascopic color unknown; metallic; opaque.
In reflected light: pale yellowish pink, no anisotropism, no bireflectance, nonpleochroic. R: (23.2 %)470nm, (23.7 %) 546nm, (24.0 %)589nm, (23.8 %)650nm.
4.36 (1), 3.38 (1), 3.08 (10), 2.67 (2), 1.887 (7), 1.612 (5), 1.543 (1), 1.333 (1), 1.225 (1), 1.192 ( ).

$Na_4Zn_2Si_7O_{18}\cdot 5H_2O$

IMA No. 92-040
Orthorhombic: F2dd
a 10.211 b 39.88 c 10.304 Å
Colorless to light mauve; vitreous; transparent.
Biaxial (+), α 1.520, β 1.521, γ 1.524, 2V(meas.) 61°, 2V(calc.) 60°.
6.346 (10), 4.959 (3), 3.240 (6), 3.167 (4), 3.140 (4), 2.821 (3).

$(Tl,K)Fe_3(SO_4)_2(OH)_6$

IMA No. 92-041 The thallium-analog of jarosite.
Hexagonal (trigonal): $R\bar{3}m$
a 7.3301 c 17.6631 Å
Gold-yellow; adamantine; transparent.
Uniaxial (-), ω 1.822, ε 1.768.
5.974 (87), 3.666 (34), 3.112 (100), 2.9877 (22), 2.5773 (21), 1.9912 (29), 1.8329 (23).

$Ca(UO_2)_4(SO_4)_2(OH)_6\cdot 6H_2O$

IMA No. 92-043
Orthorhombic: P-lattice, space group unknown
a 8.73 b 17.09 c 15.72 Å
Sulphur-yellow; vitreous; translucent.
Biaxial (-), α 1.617 (calculated), β 1.710, γ 1.758, 2V(meas.) 68°.
7.90 (100), 4.17 (30), 3.98 (40), 3.49 (80), 3.38 (70), 2.844 (30b).

$PbFe^{3+}_3(PO_4)_2(OH,H_2O)_6$

IMA No. 92-045 The phosphate-analog of segnitite.
Hexagonal (trigonal): $R\bar{3}m$
a 7.325 c 16.900 Å
Cream to brownish yellow to yellowish green; adamantine; translucent.
Uniaxial (-), ω 1.955, ε 1.935.
5.96 (90), 3.67 (60), 3.07 (100), 2.538 (50), 2.257 (50), 1.979 (50).

$AlF_3\cdot 3H_2O$

IMA No. 92-046
Tetragonal: P4/n
a 7.715 c 3.648 Å
Colorless; vitreous; transparent.
Uniaxial (-), ω 1.427, ε 1.403.
5.47 (100), 2.439 (72), 2.027 (70), 1.775 (78), 1.725 (85), 1.306 (70).

$Na_4REE_2(CO_3)_5$ with Ce the dominant REE

IMA No. 92-048
Monoclinic: $P2_1$
a 20.84 b 6.374 c 10.578 Å β 120.45°
Gray with slight pinkish tint; vitreous; translucent.
Biaxial (+ or -), α 1.623, β 1.636, γ 1.649, 2V(meas.) 90°, 2V(calc.) 89°.
9.13 (3), 5.22 (5), 4.13 (3), 3.70 (4), 2.607 (10), 2.148 (3), 1.921 (3).

$(Mg,Ti,\square)(Al,Mg)_2Al_4Si_3O_{18-x}(OH)_xB$ $x \approx 3$

IMA No. 92-050 The magnesium-analog of dumortierite.
Orthorhombic: Pmcn
a 12.02 b 20.22 c 4.732 Å
Pink to red; vitreous; transparent.
Biaxial (-), α 1.678, β 1.700, γ 1.701, 2V(meas.) 38°, 2V(calc.) 24°.
6.01 (59), 5.88 (100), 3.489 (60), 3.255 (82), 3.074 (53), 2.927 (74), 2.131 (50),
2.090 (48).

NOTE:

The following three minerals from previous years also have been approved.

$Fe_{16}O_{16}(OH)_y(SO_4)_z$ where $16 - y = 2z$ and $2.0 \le z \le 3.5$

IMA No. 90-006
Tetragonal: probably P4/m
a 10.66 c 6.04 Å
Brownish yellow; dull; translucent.
Optical properties unknown.
4.86 (37), 3.38 (46), 2.55 (100), 2.28 (23), 1.66 (21), 1.51 (24), 1.46 (18).

$(U,Y)(Ti,Nb,Ta)_2O_8$

IMA No. 90-046 The uranium-analog of polycrase-(Y).
Orthorhombic: Pbcn
a 14.48 b 5.559 c 5.223 Å
Brown-red; adamantine; opaque.
In reflected light: pale gray with bluish tones; no anisotropism, bireflectance, or pleochroism. R: (23.6 %)470nm, (21.5 %) 546nm, (22.3 %)589nm, (25.1 %)650nm.
3.73 (W), 3.21 (W), 2.99 (S), 2.78 (W), 1.90 (MS), 1.86 (W), 1.77 (MW), 1.48 (M).

$Fe_2(OH)_3Cl$

IMA No. 91-036
Orthorhombic: Pnam
a 6.31 b 9.20 c 7.10 Å
Megascopic color unknown; luster probably dull; transparent.
Index of refraction: 1.6 to 1.7.
Electron diffraction pattern: 5.68, 5.07, 2.93, 2.37, 2.14, 1.65.

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