with volcanic eruptions, has generally been confined to such factors as the ratio of pyroclastics to effusive products for a particular eruption [for example, see A. Rittman, *Volcanoes and Their Activity* (Interscience, New York, 1962)]. While clearly logical, such a definition should not prevent use of the term when different techniques and concepts are developed to study the same phenomenon. Our model is designed to measure volcanic cloud heights, and we prefer to use a simple transformation of the result into the equivalent explosive energy needed to create such a cloud (*7*).

9. After the cloud height is computed using methods described in Shaw *et al.* (*7*), the equation of B. R. Morton, G. Taylor, and J. S. Turner [*Proc. R. Soc. London Ser. A* **234**, 23 (1956)] can be applied to derive explosive energy in joules. The result can then be expressed in megatons of TNT equivalent, where 1 megaton = 3.4×10^{15} joules. We stress here that the equation of Morton *et al.* relating cloud height and explosivity can be one of two types, depending on whether the explosion is assumed to be instantaneous or of long duration. The latter assumption results in explosivity estimates up to two orders of magnitude higher. In our analyses we assume instantaneous explosions, and therefore obtain minimum estimates of the energy released to form volcanic clouds at the independently computed heights.
10. The between-core downwind decrease in the volcanic glass accumulation rate for the series of eruptions (Fig. 1a) was used to compute, by exponential extrapolation, the distance at which the rate reaches zero (the maximum distance traveled by the ash). This was done for each separate volcanic dust layer, using the mean for each of three separate particle size ranges: 45 to 36, 35 to 29, and 28 to 23 μm. The apparent cloud height was then derived for each particle size, using equations summarized graphically in figures 5 and 7 of Shaw *et al.* (*7*), and the results were averaged before application of the equation of Morton *et al.* (*9*) relating cloud height to explosivity. Eleven eruptions (*1*, table 4) were amenable to this analysis (eruptions B1, B2, B3, C1, C2, C3, D2, D3, E5, F2, and F3 in Fig. 1a of this report).
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Sebertia acuminata: A Hyperaccumulator of Nickel from New Caledonia

Abstract. Sebertia acuminata *(Sapotaceae) from New Caledonia has been shown to be a hyperaccumulator of nickel. The nickel content of the latex (25.74 percent on a dry weight basis) is easily the highest nickel concentration ever found in living material. The nickel is in the form of a low-molecular-weight, water-soluble organic complex.*

In recent years a number of plant species have been discovered which have very high concentrations of nickel (*1–5*). Species containing over 1000 μg (0.1 percent) of this element per gram (dry weight basis) have been termed hyperaccumulators (*5*). The unusual aspect of these accumulators is that with the exception of *Hybanthus floribundus* from Western Australia (*2*) and *Alyssum bertolonii* from Italy (*1*) the species discovered so far are confined exclusively to New Caledonia and are mainly of the genera *Homalium* and *Hybanthus* (see Table 1).

The existence of these accumulators has caused considerable interest in the fields of mineral exploration and plant physiology because of the possible association of these plants with nickel mineralization and because of the interesting problems in plant physiology posed by such high accumulations of an element normally toxic to plants.

We have recently discovered the unusually high nickel-accumulating ability of *Sebertia acuminata* Pierre ex Baill. (Sapotaceae). This species is a tree which reaches 10 m in height. It is well known in New Caledonia from the blue-green color of its latex and is therefore known locally as Sève bleue (blue sap). *Sebertia acuminata* is endemic to New Caledonia, is relatively rare, and has never been recorded away from ultrabasic substrates. It is found mainly in the Grand Massif du Sud and in the Tiebaghi Massif in the north of the island, is found more often in forested areas over peridotitic alluvia or colluvia relatively rich in nickel. A typical soil would contain (in approximate percentages) nickel, 0.85;

Table 1. Nickel concentrations in *Sebertia acuminata* compared with values for other hyperaccumulators.

Species	Organ	Locality	Conc. of nickel (percent dry weight)	References
Sebertia acuminata	Latex	New Caledonia	25.74 (11.20*)	This report
	Leaves		1.17	
	Trunk bark		2.45	
	Twig bark		1.12	
	Fruits		0.30	
	Wood		0.17	
Hybanthus floribundus	Leaves	Western Australia	0.71	(*2, 6*)
	Stems		0.26	
	Wood		0.15	
	Fruits		0.13	
	Flowers		0.48	
	Trunk bark		0.17	
Alyssum bertolonii	Leaves	Italy	0.80	(*1*)
Homalium austrocaledonicum	Leaves	New Caledonia	0.18	(*5*)
H. deplanchei	Leaves	New Caledonia	0.19	(*5*)
H. francii	Leaves	New Caledonia	1.45	(*5*)
H. guillainii	Leaves	New Caledonia	0.69	(*3, 5*)
H. kanaliense	Leaves	New Caledonia	0.94	(*4, 5*)
H. mathieuanum	Leaves	New Caledonia	0.17	(*5*)
H. rubrocostatum	Leaves	New Caledonia	0.12	(*5*)
Hybanthus austrocaledonicus	Leaves	New Caledonia	1.38	(*3–5*)
H. caledonicus	Leaves	New Caledonia	0.60	(*3–5*)
Psychotria douarrei	Leaves	New Caledonia	3.40	(*3*)
	Fruits		2.30	
	Trunk bark		5.24	
	Twig bark		5.52	
	Flowers		2.40	
	Wood		0.23	

*Value expressed on wet weight basis.

iron, 45; aluminum, 8.5; silica, 6; chromium, 3; cobalt, 0.10; potassium, 0.02; calcium, 0.06; and magnesium, 2.

It should be noted that *S. acuminata* is the fourth hyperaccumulator of nickel [that is, after *Hybanthus austrocaledonicus*, *Homalium guillainii*, and *Psychotria douarrei* (*3*)] discovered in the same location. This area consists of dense humid forest over peridotitic humus-rich alluvia in the vicinity of the Rivière Bleue. It would therefore seem that, unlike the case of *Hybanthus floribundus* (*6*), accumulation of nickel is not a xerophytic adaptation.

Table 1 shows the nickel content of various organs of *S. acuminata*. The data are based on the analysis of three specimens (one from the Rivière Bleue area, one from the Tontouta area, and another from the Forêt Cachée).

The nickel content of leaves and of other organs is very high (~ 1 to 2 percent), although comparable with most other hyperaccumulators from New Caledonia. Of special significance, however, is the extremely high nickel content of the latex which has 11.20 percent nickel on a wet weight basis and 25.74 percent when the data are expressed on a dry weight basis. This nickel concentration is nearly five times higher than for any other part of any other species and is easily the highest nickel concentration ever reported for any other living material (see Table 1). The cobalt content of the latex (0.007 percent) is extremely low compared with that of nickel. Values for other elements (in percentages: iron, 0.06; chromium, 0.004; potassium, 0.15; sodium, 0.11; magnesium, 0.052; and calcium, 0.52) are also relatively low.

The extremely high nickel content of the latex of *S. acuminata* poses interesting problems in plant physiology, since nickel contents as high as this would be fatal for most phanerogams. Preliminary experiments in our laboratory have resulted in the isolation of a low-molecular-weight, water-soluble organic complex of nickel whose composition has not yet been determined.

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Subjective Measurement of High-Order Aberrations of the Eye

Abstract. *We used an apparatus similar to Tscherning's aberroscope, and analyzed subjects' drawings to obtain the wave aberration surfaces of 55 eyes. This analysis permitted a Taylor series representation of the wave aberrations to terms of the fourth order. The results revealed a wide variety in type and severity of high-order aberrations in which "cylindrical" aberrations were prominent and cases of classical spherical aberration were rare. We computed the monochromatic modulation transfer function curves for the range of observations. The overall findings suggest a more prominent role for monochromatic high-order aberrations in degrading the visual image than has hitherto been assumed.*

Ordinary refractive corrections embodied in prescription spectacles specify three parameters for each lens (neglecting prism), namely, the sphere, cylinder, and cylinder axis. High-order monochromatic aberrations of the eye, for example, spherical aberration and coma, are usually neither diagnosed nor treated despite the famous dictum of Helmholtz (*1*) that the aberrations of the eye are such as would not be tolerated in any good optical instrument. With regard to diagnosis, this situation is doubtless due to the great difficulty attending most methods of aberration measurement hitherto employed (*2*).

We have developed a new subjective method for measuring the monochromatic aberrations of the eye (Fig. 1). The method is similar to that used with Tscherning's aberroscope (*3*). The subject monocularly views a point source of monochromatic light through a crossed-cylinder lens and grid assembly, which is held in a trial frame with the subject's normal distance lenses. Due to the strong astigmatism induced by the crossed-cylinder lenses, the pattern of the grid at the pupil is reproduced as a shadow image on the subject's retina, rotated through 90°, reversed left to right, and distorted by the aberrations of the subject's eye as follows: with no aberrations, the grid at the pupil will be transformed into a perfectly square grid on the retina and perceived as such. If, however, we envision an aberrant wave front at the pupil deviating from a perfect sphere by a distance $W(x,y)$ at any point, x,y, then the corresponding point on the retina, x',y', will be displaced from its aberration-free location by the amounts $\Delta x'$ and $\Delta y'$ where

$$\Delta x' = F(dz/dy) \quad (1)$$

$$\Delta y' = F(dz/dx) \quad (2)$$

and F is the focal length of the eye (*4*).

Whereas conventional lens aberration theory is based on the assumption of rotational symmetry of the optical elements, we have chosen to describe the wave-front aberration by a Taylor series, which makes no assumptions about the symmetry of the elements. Thus we may describe the wave-front aberration, $W(x,y)$ in terms of its coordinates x and y with origin at the center of the pupil (*5*):

$$W(x,y) = A + Bx + Cy + Dx^2 + Exy + Fy^2 + Gx^3 + Hx^2y + Ixy^2 + Jy^3 + Kx^4 + Lx^3y + Mx^2y^2 + Nxy^3 + Oy^4 \ldots \quad (3)$$

In this series representation of the wave aberration surface the terms Bx and Cy correspond to the conventional horizontal and vertical prism terms in an ophthalmic prescription and the terms Dx^2, Exy, and Fy^2 are transforms of the ordinary sphere, cylinder, and axis. The high-order aberrations are embodied in the subsequent terms, which we have represented through the fourth order. Each of these nine high-order terms gives rise to a characteristic distortion of the grid pattern resulting either in curvature or nonparallelism of the lines of the pattern (*6*) (Fig. 1). Terms with coefficients G through J specify third-order (comalike) aberrations while terms with coefficients K through O represent fourth-order aberrations. Classical spherical aberration is represented by the three terms K, M, and O in the ratio of 1 : 2 : 1. The pattern that the subject sees may be regarded as a square grid distorted in a manner determined by the Taylor series of Eq. 3, for which coefficients G through O are to be determined.

Each subject was asked to draw the pattern as he or she saw it. The locations of the intersections in the drawings were then recorded, and the Taylor