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Introduction

The roots of early interest by the first author in the *Brassicaceae* go back to the mid 1960s after finishing college and working in one of the Baghdad herbaria, but knowledge of the family did not expand until subsequent higher studies in the West. It soon became evident that in order to learn more on the family, key references such as CANDOLLE (1821a), BOISSIER (1867a), and SCHULZ (1936) should be constantly consulted. It is quite evident that subsequent *Brassicaceae* accounts for the floras of the former Soviet Union (BUSCH, 1939), Turkey and East Aegean Islands (DAVIS, 1965a), and Afghanistan, Iran, Iraq, and Pakistan (RECHINGER, 1968) would have been severely delayed or hampered had it not been for BOISSIER's (1867–1888) monumental *Flora Orientalis*.

The foundation of the *Flora Orientalis* is the G-BOIS herbarium, which includes the collections of Boissier and numerous other botanists that are kept separate from the other herbaria of the Conservatoire et Jardin botaniques de la Ville de Genève (hereafter G). It is by far one of the richest herbaria in the world in type collections from that area, especially for Southwest Asia, Caucasus, and Balkan Peninsula. Obviously, no sound taxonomic conclusions can be made without consulting the types of that herbarium.

The *Brassicaceae* is extremely rich in the Irano-Turanian region, Southwest Asia and the Caucasus undoubtedly represents the main center of the family diversity. The *Cruciferae* account in the *Flora Orientalis* (BOISSIER, 1867a) and its *Supplementum* (BOISSIER, 1888) occupy a total 310 pages, and the total number of taxa treated are approximately 940 species and varieties, of which 532 taxa (56.6%) were described by Boissier either alone or in collaboration with other botanists. However, the bulk of novelties appeared prior to these two publications (see BOISSIER, 1841a, 1841b, 1842a, 1842b, 1842c, 1843, 1844, 1846, 1849, 1854, 1856, 1859). All 532 novelties are dealt with in this paper, and the holotypes or previously designated lectotypes are listed, discussed, and evaluated.

As a consequence of the lack of detailed guidelines for lectotypification of taxa in the *International Code of Nomenclature for algae, fungi, and plants* (TURLAND et al., 2018), many botanists lectotypified Boissier's novelties arbitrarily and regardless to whether or not Boissier had examined authentic material of a given institution and whether or not they are deposited in the G-BOIS herbarium. In fact, as the reader goes through the typifications below, it is easy to see that in some exceptional cases typifications were based on material allegedly present in G-BOIS when in fact it never existed there in the first place. We are always reminded by ROLLINS (1972, 1980) who emphasized the need to pay extreme care in lectotypifying taxa. Because of artificial or careless lectotypifications and because of the absolute importance of G-BOIS herbarium in studying the *Brassicaceae* of Southwest Asia and neighboring regions, the first author decided to undertake this challenging task and

deal with every taxon described by Boissier and co-workers. In that, the sequence of taxa follows the *Flora Orientalis* and its *Supplementum*. However, before jumping on the enumeration of taxa, some background on Boissier and his work are necessary.

Pierre-Edmond Boissier

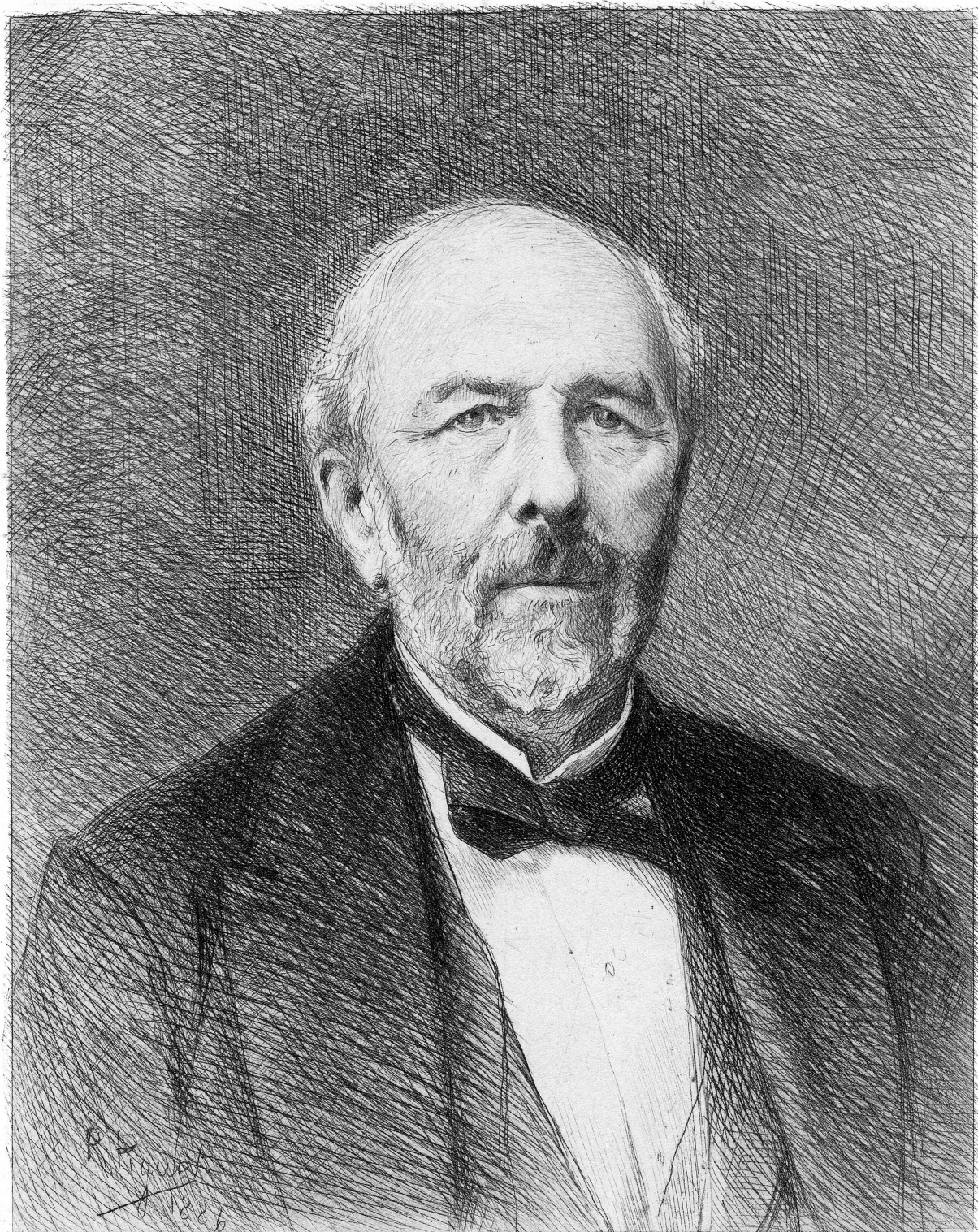
Pierre-Edmond Boissier (Geneva: 25 May 1810 – Valeyres-sous-Rances: 25 September 1885) (Fig. 1), an outstanding Swiss botanist, explorer, and mathematician, was one of the most productive taxonomist of the 19th century, and his scientific output is perhaps comparable only to that of his fellow citizen and mentor Augustin-Pyramus de Candolle (1778–1841). Boissier was privately educated at home mainly in French, Latin, and Italian, and his love of botany stems back to his childhood when his grandfather, Pierre Butini (naturalist and physician), took him, along with his sister and mother, on trips to Jura and the Swiss Alps. After taking courses in botany with Candolle at the Academy of Geneva, Boissier completed his studies in Paris in 1831–1832 with Jacques Étienne Gay (1786–1864) and Philip Barker Webb (1793–1854).

There is a wealth of literature covering Boissier's family, education, travel, friends, discoveries, gardening, herbarium, publications, and correspondences, and the interested reader is highly recommended to consult various publications commemorating him, including at least CHRIST (1888), CHODAT et al. (1935–1936, and articles within), RECHINGER (1969), STAFLEU (1970), BURDET (1985), LIÈVRE (1994), CHARPIN (2011), COVILLOT (2011), GRENON (2011), and JACQUEMOUD (2011). However, matters only directly related to the *Flora Orientalis* are briefly dealt with here.

Collections and collectors

STAFLEU (1970: 803) described Boissier as “...financially independent, healthy and strong, a born traveler and mountaineer, gifted with unusual mnemonic powers, and a consistent worker”. Boissier continued to collect from 1832 to 1885, the year he passed away. In 1840, he married his cousin, Lucile Butini. Based on the recommendations of Candolle and Webb, Boissier collected in the Iberian Peninsula nine times, including in 1849 when he was accompanied by his wife who died during their travel to Spain and Algeria.

Shortly after purchasing in 1840 of an almost complete set (perhaps over 5400 numbers; see BOISSIER, 1888) of Aucher-Eloy collections from the ‘Orient’ and immediately after the recognition of numerous undescribed species and genera, Boissier became interested in the plants of what became the *Flora Orientalis* area. His first trip was in 1842 and then with his wife in 1845–1846. They collected in Greece, western Turkey, eastern Egypt along the Nile, Sinai Peninsula, Israel, Lebanon, and Syria, and details of his voyages were mapped with chronologically numbered localities and excellent discussions



R. Piguet, del. & sc.

Fig. 1. Portrait of Edmond Boissier (1810–1885). Engraving by R. Piguet.
[Bibliothèque des Conservatoire et Jardin botaniques, Genève]

by MERMOUD (1980) and CHARPIN (2011). The complete set of Boissier collections is in G-BOIS, and duplicates are currently housed in: A, AK, B, BERN, BM, BORD, BP, BR, C, CAS, CGE, CN, DBN, E, F, FABR, FI, G, GE, GH, GOET, H, HAL, JE, K, KIEL, KW, L, LAU, LE, LY, LZ, M, MA, MANCH, MICH, MO, MPU, OXF, P, PH, PI, STR, TCD, TO, US, VR, W, WAG, WB, WU, Z, and ZT.

Numerous collectors and collaborators worked closely with Boissier, and their collection numbers and citations in the *Flora Orientalis* volumes were presented in the supplementary volume (BOISSIER, 1888: 415–466). Some of them collected several *Brassicaceae* specimens from limited geographical areas, and they will not be mentioned in this paragraph, and their initials and last names will be listed under the type material they collected. However, others were prolific collectors, and only their last names are cited in the typified taxa below. Among the most notable of them was Pierre Martin Rémi Aucher-Eloy (1792–1838), a French pharmacist who collected in Greece, Turkey, and Egypt eastward into Oman and Iran. Another was Karl Georg Theodor Kotschy (1813–1866), an Austrian botanist and explorer who collected over 300,000 specimens from throughout the *Flora Orientalis* area. In addition, many other botanists sent their collections to Boissier or collected with him, and they include the Austrian Friedrich Wilhelm Noë (1798–1858); British William Griffith (1810–1845), John Ellerton Stocks (1822–1854), and James Edward Tierney Aitchison (1836–1898); French Georges François Reuter (1805–1872), Eugène Bourgeau (1813–1877), Joseph Arnaud Charles Gaillardot (1814–1883), Charles Isodore Blanche (1823–1887), Gaspard Joseph “Benjamin” Balansa (1825–1891), and Alfred Huet du Pavillon (1829–1907); German Georg Heinrich Wilhelm Schimper (1804–1878), Wilhelm von Spruner (1805–1874), Theodor Heinrich Hermann von Heldreich (1822–1902), and Heinrich Carl Haussknecht (1838–1903); Greek Theodoros G. Orphanides (1817–1886); Latvian Friedrich Alexander Buhse (1821–1898); Russian Alexander Andreevich von Bunge (1803–1890).

Coverage

The idea of writing the *Flora Orientalis* went on the back of Boissier's mind shortly after he acquired Aucher-Eloy plants and conducted his fieldwork in the Orient in 1842, 1845, and 1846. Perhaps it was crystallized after receiving a letter from William Jackson Hooker on 9 September 1847. It is currently in the Archives of the Conservatoire et Jardin botaniques of Geneva, and according to LIÈVRE (1994: 136) Hooker said “No one can do it [*Flora Orientalis*] as well as you can, and from no one will it be more acceptable. Everything west of the Indus belongs to that *Flora*”.

The *Flora Orientalis* area was roughly outlined on a map by RECHINGER (1969) (Fig. 2) and better delimited to countries by JACQUEMOUD (2011). Upon overlapping that map over

the phytogeographical regions presented by HEDGE (1976), the *Flora* area covers the eastern Mediterranean, nearly half of the Saharo-Sindian, and the vast majority of the Irano-Turanian regions. In terms of coordinate coverage, that area roughly falls between 19°E in Albania and 29°E in Egypt eastward to 66°E in Baluchistan (Pakistan) northward into easternmost Afghanistan, Turkmenistan, and Uzbekistan (Tashkent). The southern and northern limits include north of Aswan (Egypt) at about 27°N into the upper half of Saudi Arabia into Masqat (Oman) to the west of Karachi (Pakistan) and from Uzbekistan into Turkmenistan and Kazakhstan across roughly the upper two thirds of the Caspian Sea, all Caucasus (including the Russian part) and Crimea, into the upper half of Albania at about 41°N. This tremendously huge area covers the entire Greece, Cyprus, Turkey, the Caucasian countries (Armenia, Azerbaijan, and Georgia), Syria, Lebanon, Israel, Jordan, Iraq, Iran, most of Oman, and Turkmenistan.

The localities given in this work follow the original publications, though the current geography is used for the countries. For example, what was Armenia during the publication span of the *Flora*, i.e. during the Ottoman Empire, included both current Armenia, Azerbaijan, Georgia, Iranian Azerbaijan Province, and the eastern half of Turkey. Many collectors, including Aucher-Eloy, Buhse, Bunge, Kotschy, Huet du Pavillon, and Szovits loosely used “Armenia” to indicate that broad geographic region.

Publications

Excluding many articles published in various journals, the complete list of Boissier's publications are given in STAFLEU & COWAN (1976), including the ones related to countries not covered by the *Flora Orientalis*. For the *Cruciferae* of *Flora Orientalis*, the important works are *Plantae Aucherianae orientales* published in *Annales des Sciences Naturelles* – hereafter *Annales* (BOISSIER, 1841a, 1841b, 1842a, 1842b, 1842c), followed chronologically by *Diagnoses plantarum orientalium novarum* – hereafter *Diagnoses* (BOISSIER, 1843, 1844, 1846, 1849, 1854, 1856, 1859), plants of the Transcaucasus and Persia (BOISSIER & BUHSE, 1860), and ending with the monumental *Flora Orientalis* (BOISSIER, 1867a) and its *Supplementum* (BOISSIER, 1888: 29–67) published three years after Boissier's death (Fig. 5–6, p. 49–50).

The *Diagnoses* and *Flora Orientalis* remain the key references to the present on the vascular floras of Southwest Asia and, together with G-BOIS, they were vital for the production of subsequent floras of the area, especially the *Flora of Turkey* and *Flora Iranica*.

Although some *Brassicaceae* floras with a broadly defined species concept (e.g., *Flora Europaea* and to a lesser degree *Flora of Turkey* vol. 1) reduced many of Boissier's taxa to synonymy, the first author agrees with RECHINGER (1969) that Boissier's narrower species concept is usually justified at least

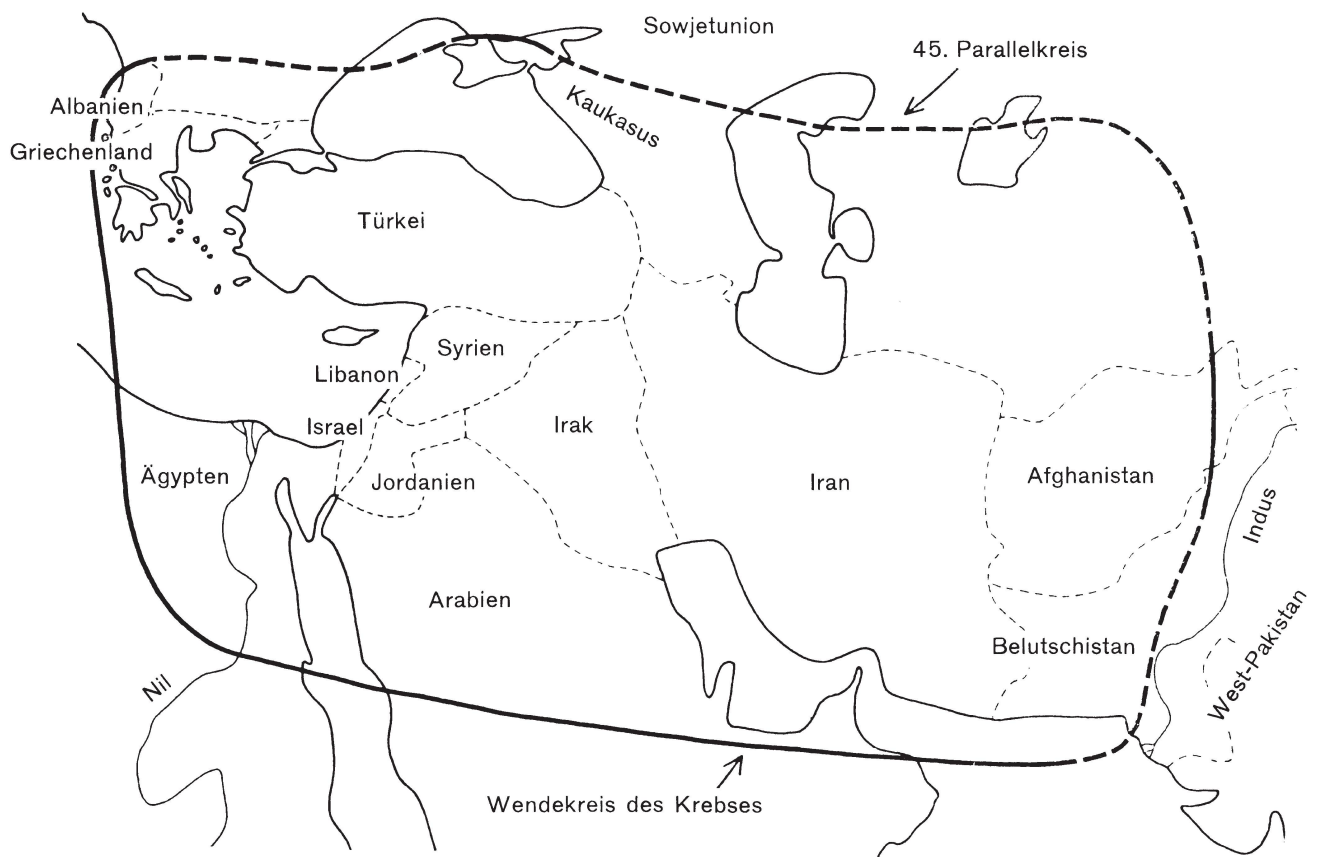


Fig. 2. Area Map of *Flora Orientalis* from RECHINGER (1969: viii).
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for the *Brassicaceae*, where 273 of the 399 species (or 68 %) that were described by him and his coauthors as new are currently accepted in the same original genera or transferred to others. For the varieties, it is the opposite because only about 6.1 % (6 out of 98) are currently recognized.

As enumerated by STAFLEU (1970), Boissier described about 6,000 new species, of which 3,336 were published in his *Diagnoses*, and finally the entire *Flora Orientalis* volumes and its *Supplementum* include the descriptions of 11,631 species. Boissier collaborated with numerous botanists, and he co-authored 2,388 novelties with them, notably Reuter (LIÈVRE, 1994).

Boissier herbarium

The history of Boissier's herbarium and library from its foundation, locations, and various curators to the present are well-covered by JACQUEMOUD (2011), and the interested reader should consult that valuable contribution. One important aspect to mention, however, is that the *Flora Orientalis* herbarium was originally not maintained separately from the remainder of Boissier's herbarium. Boissier and his son in law William Barbey (1842–1914) herbaria were given by Barbey's sons to the University of Geneva (Fig. 3, p. 14) in 1918 with an inauguration on June 5, 1919, to be maintained and curated through generous financial support (LIÈVRE, 1994; JACQUEMOUD, 2011). These two herbaria were then officially donated to the Conservatoire et Jardin botaniques in 1944, but physically transferred and housed together with those of Candolle, Delessert, and others from 1958 to the present. Starting in 1963 under the impulse of the former director Charles Baehni (1906–1964) the specimens related to *Flora Orientalis* have been meticulously extracted from the rest of the Boissier herbarium, remounted and rearranged in the original sequence of the *Flora* (JACQUEMOUD, 2011) (Fig. 7, p. 51). They are since kept separate, excluded from loan, their classification and sequence cannot be changed, and became accessible as G-BOIS only since 1974 (Fig. 4, p. 15). Consequently, in the floras published before this date (e.g., *Flora Iranica*, *Flora of Turkey*) when G is listed, it meant G-BOIS.

Although the herbarium sheets in the Boissier herbarium are distinctly larger in size than the vast majority of those in the other Geneva herbaria, the individual gatherings of a taxon by Boissier or his colleagues from a given locality often did not fit on a single sheet. Such single gatherings were kept in collection folders of few to several sheets at least one of which was fully labelled and the others remained unlabeled or have very abbreviated labels written by Boissier to indicate only partial information from the fully-labeled sheet. A few examples include a collection folder of up to seven sheets in *Alyssum cassium* or up to five sheet each in *Alyssum crenulatum* Boiss. & Heldr., *Erysimum gladiiferum* Boiss. & Hausskn., *Hesperis violacea* Boiss. (Fig. 8, p. 52), and *Hussonia uncatata* Boiss.

Until recently, there has been a great deal of controversy among botanists unfamiliar with the way the Geneva herbaria have been operating for nearly the past century and a half, and some workers considered only the fully labelled sheets as type material, while ignoring the unlabeled ones or considering the partially labeled ones as syntypes, isotypes, or isolectotypes. The problem was fully discussed by GAUTIER et al. (2016), and their proposal submitted at the International Botanical Congress in Shenzhen (TURLAND & WIERSEMA, 2017) was approved. The Shenzhen Code (Art. 8.3, Ex. 9, in TURLAND et al., 2018: 18) specifically mention this situation: "In the Geneva herbaria, a single specimen is often prepared on two or more sheets, which are not therefore duplicates. Although the individual sheets are usually not labelled as being part of the same specimen, they are physically kept together in their own specimen folder and bear a single, original label in common" (see Fig. 8, p. 52). Therefore, from here on, a given multisheet folder containing a holotype, isotype, lectotype, or syntype in G-BOIS is treated as a unit rather than by its individual sheets. Accordingly, and for an example, the phrase "The lectotype is a collection folder of x sheets" is used throughout this work.

As frequently happened, the holotypes or lectotypes of taxa described by Boissier have handwritten labels by their original collectors. When duplicates are sent as exsiccatae, printed, handwritten labels by Boissier often do not include the collection day or number. In numerous cases, material gathered by foreign collectors are sent to Boissier for determination but initially with provisional numbers on handwritten labels. Following determinations, the information was sent back to the collectors and the remaining duplicates were distributed with different numbers. Many such cases have been encountered and discussed in this work, especially for the collections of Balansa, Heldreich, and Kotschy. Indeed, because the isolectotypes (or isotypes) can have different labels with different collection numbers, some botanists erroneously believe that the two types of labels denote different collections.

Cruciferae in the Flora Orientalis

Boissier described an impressive 132 new genera of vascular plants, and only a few of them were co-authored with or published for other botanists. Of the 132 total, 28 genera (ca. 21 %) were in the *Cruciferae*, 14 are currently accepted, and three (*Buchingera* Boiss. & Hohen., *Diceratium* Boiss., *Pyramidium* Boiss.) of the 14 synonymized were later homonyms. The genera are: *Alyssopsis* Boiss., *Brossardia* Boiss. (= *Noccaea* Moench), *Buchingera* (= *Asperuginoides* Rauschert), *Campyloptera* Boiss. (= *Aethionema* W.T. Aiton), *Chalcanthus* Boiss. (= *Eutrema* R. Br.), *Chrysochamela* (Fenzl) Boiss., *Clastopus* Bunge ex Boiss., *Coluteocarpus* Boiss. (= *Noccaea*), *Crenularia* Boiss. (= *Aethionema*), *Diceratella* Boiss., *Diceratium* (= *Diceratella* Boiss.), *Didymophysa* Boiss., *Eremobium* Boiss., *Fortuynia* Shuttlew. ex Boiss., *Glastaria* Boiss., *Graellsia* Boiss.,

Heldreichia Boiss., *Hussonia* Boiss. (= *Erucaria* Gaertn.), *Iberidella* Boiss. (= *Noccaea*), *Moriera* Boiss. (= *Aethionema*), *Nasturtiopsis* Boiss., *Parlatoria* Boiss., *Physoptychis* Boiss., *Pyramidium* Boiss. (= *Veselskya* Opiz), *Strigosella* Boiss., *Strophades* Boiss. (= *Erysimum* L.), *Tchihatchewia* Boiss. (= *Hesperis* L.), and *Zerdana* Boiss. (= *Sterigmostemum* M. Bieb.).

Typification

As shown throughout the text, many authors of various floras often artificially typified the *Brassicaceae* taxa described by Boissier based on material they did not examine and currently housed in herbaria other than those in Geneva. By contrast, for taxa typified here, the first step was checking the holdings in G-BOIS and the original protologues to find out if Boissier indicated that he examined such material in other herbaria. In typifying taxa described by Boissier in *Flora Orientalis*, Boissier clearly stated that first he examined the specimens in his own herbarium (G-BOIS) and then, if necessary he completed with specimens deposited in other herbaria, most of all B, LE and W as loans and the herbaria of Paris and London that he visited (BOISSIER, 1867b). Likewise, we consider for the typification of the taxa described in the *Diagnoses* that Boissier consulted specimens of the same herbaria.

In typifying taxa described by Boissier in the *Annales*, almost all authors overlooked BOISSIER (1841a) and the footnote by the editor of that publication. Boissier clearly stated that he based that series on Aucher-Eloy's collections in his own herbarium (now in G-BOIS) and that of Candolle. As Aucher-Eloy's collections were received by Candolle in 1837, *i.e.* after the publication of volume 1 of the *Prodromus* in which the *Cruciferae* are treated (CANDOLLE, 1824), these collections are not in the *Prodromus* herbarium (G-DC), but have been incorporated in the general collection G. All duplicates in these herbaria were checked because of their importance in the typification of taxa described by BOISSIER (1842a, 1842b, 1842c). Boissier did not examine the rich Aucher-Eloy collections in the Moricand or Delessert herbaria because they were not available in G on 1842, but he checked and annotated numerous duplicates at P. Some novelties were based on Aucher-Eloy unicates at P sent to Boissier by A. Brongniart, and these are recognized here as holotypes. He always annotated the specimens examined from other herbaria, and those unannotated (including those in P, or G with a label of Candolle's herbarium) are interpreted here as not examined. Boissier's unique handwriting easily distinguishes his annotations from those of other botanists of his time.

If Boissier did not annotate or mention the source of material he studied, it is a definite rule that he based his descriptions *solely* on the material in his herbarium, and in the majority of cases he cited a single collection for a given taxon. Therefore, there is no justification to list a holotype or designate a lectotype based on material not studied by Boissier from any other herbarium. This matter is clearly indicated in the Code

(Article 9.1, note 1; TURLAND et al., 2018): "If the author used only one specimen or illustration, either cited or uncited, when preparing the account of the new taxon, it must be accepted as the holotype". This important note is enforced in identifying a given holotype, as well as in designating a lectotype, in a herbarium other than G-BOIS if it lacks Boissier's annotation or citation in the protologue. Such erroneous designations are either ignored or corrected by a second-step lectotypification throughout this work.

As for GAY's (1842) species novelties of *Erysimum*, it is clear that their names have priority because his account was published on 20 January 1842, whereas Boissier's (1842a) names in *Annales* were published in March of that year. Two of Gay's species, *E. purpureum* and *E. pycnophyllum*, are lectotypified in this work, and they are based on the same type collections of Boissier's illegitimate later homonym *E. purpureum* and name superfluous *E. thyrsoideum* respectively.

Sequence of the text

BOISSIER (1867a) partially adopted CANDOLLE (1821a, 1821b, 1824) classification system of the *Cruciferae* by recognizing only three of the five major "*subordo*". He united the *Pleurorhizeae* DC. and *Notorhizeae* DC. into *Platylobeae* Boiss., maintained *Orthoploceae* DC. and *Spirolobeae* DC., and did not include *Diplocolobae* DC. because it is an exclusively South African group. Furthermore, he did not recognize any of the 21 tribes of Candolle, of which many were recognized by subsequent botanists to the present. Boissier divided the three *subordo* into informal groups based on descriptive terms applied to fruit length/width ratio (e.g., *Siliquosae*, *Siliculosae*), type of fruit flattening (*Angustiseptae*, *Latiseptae*), and cotyledonary position (*Notorhizeae*, *Pleurorhizeae*). These descriptive fruit and embryo types were originally introduced by CANDOLLE (1821a, 1821b). For a comparison of the two systems and generic arrangements of Candolle and Boissier, the reader is advised to consult HAYEK (1911).

Except for the present work, not a single other author followed BOISSIER's (1867a) generic sequence. However, the main reason for doing so here is to link the present typification with the *Flora Orientalis* sequence to facilitate easy reference and future updates. Regardless to whether or not a given genus is currently recognized, the generic sequence follows the *Flora Orientalis*. Unless otherwise indicated, under each genus the species number and current tribal affiliation follow the latest estimates by AL-SHEHBAB (2012) and/or the continuously updated *Brassicaceae* database or BRASSIBASE (2019). The aim is to aid the reader in linking the past and present knowledge of taxa.