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An Unpublished Manuscript *Geologica Japonica* by Von Siebold: Geology, Mineralogy, and Copper in the Context of Dutch Colonial Science and the Introduction of Western Geo-sciences to Japan[1]

Togo Tsukahara

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Abstract: In this article, I will discuss one important aspect of historical encounters between Western colonial scientists and Japanese nature. In

[1] This article is based on Togo Tsukahara's Master's thesis (1985), "A Study of the Beginning of Chemistry and Chemical Education in Japan," with special reference to the contribution of Ph. F. von Siebold and H. Burger in the first half of the nineteenth century (Tokyo: Tokyo Gakugei University), and a conference paper, Togo Tsukahara (1994), "The Dutch Commitment in its Search for Asian Mineral Resources and the Introduction of Geological Sciences as a Consequence," in *The Transfer of Science and Technology between Europe and Asia, 1780-1880* (Proceedings at the Occasion of Second International Conference on the Transfer of Science and Technology between Europe and Asia 1780-1880), Kyoto: International Research Center for Japanese Studies, pp. 197-228.

order to do so, I will shed new light on how geo-sciences became an object of scientific research of Japan, in the framework of Dutch colonial sciences. I will also show that Western interests in Japanese geo-sciences were primarily stimulated by economic motivations, and that, at the same time, it accompanied the process of the introduction of modern Western sciences into Japan.

It is well-known that Philipp Franz von Siebold (1796-1866) studied Japanese natural history widely, and wrote two standard works, *Flora Japonica* and *Fauna Japonica*. This paper examines a newly found unpublished manuscript *Geologica Japonica* by von Siebold, which discusses Japanese geology and mineralogy, and reports on copper mining and smelting. Mineralogical and geological collections have also been discovered in museums at Leiden, the Netherlands. These collections are now identified as the research materials used in the preparation of this manuscript, and found to be the first systematic European geo-scientific collections from Japan.

The collection of rocks and minerals from Japan has been proved as mostly collected and identified by Heinrich Burger (1806-1858), a pharmacist and assistant to von Siebold. Burger classified the collection using two nomenclature systems, those of A. G. Werner and R. Hauy.

We further point out that the Dutch were interested in the useful natural resources of their trading partner, carrying out a survey of coal mines in Japan, and the trial of tea transplantation from Japan to Java. In my research on the newly found manuscripts and collections of geology and mineralogy, I clarify that von Siebold and Burger intensively investigated Japanese copper mining and smelting. They reported their visit to the Sumitomo copper refinery at Osaka, and Burger wrote an article on Japanese copper in the journal of the Batavian Society for Arts and Sciences.

In conclusion, based on close study of newly examined manuscripts and detailed identification of geological collections, a network of interest in Japan's geology and mineralogy by Dutch colonial scientist is illustrated, and its hybrid character is demonstrated against the background of Dutch-Japan cultural exchange.

1. Preface

In the context of European expansion, the Dutch cultivated their interest in Asian metals as major intermediate traders in Southeast and East Asia.

Japanese silver and copper were among the most lucrative commodities.[2] The economic historian Kawakatsu states that Japanese metal production and subsequent monetization facilitated a surge in the Japanese economy comparable to the emergence of modem capitalism in Europe. Kawakatsu refers specifically to J. Schumpeter, indicating that control over monetary circulation was the key factor in this outgrowth from the so-called "Asiatic mode of production."[3] In his argument, he does not emphasize the negative aspects of the so-called *sakoku* 鎖国 policy.[4] Instead, he argues that governmental trade restrictions necessitated the substitution of imported commodities and that it was an incentive for the endogenous industries. Japan thus commanded its own economic development, not only in its domestic market, but also in the inter-Asian market. This structure was a factor behind the sudden surge after the closed-nation period of Meiji Japan.

Importantly, however, we should not overlook the fact that Western science and technology gradually infiltrated Japan via Dutch scientific practice, and an indigenous hybrid platform for a techno-scientific Japan emerged. The introduction of science and technology also could have been responsible for Japanese economic growth, playing a crucial role in building industries.

To illustrate a comprehensive history of techno-scientific Japan that constitutes a supplement to the economic-history argument, this paper attempts to provide an account of Dutch-Japanese exchange. In particular, the introduction of geological science and the technology of metal production are highlighted.

I will first review the Dutch colonial sciences and their influence on Japan's history of science, because Dutch scientific activities in Japan were

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[2] Kristof Glamann (1958), *The Dutch Asiatic Trade 1620-1740*, Copenhagen: Danish Science Press; Holden Furber (1976), *Rival Empires of Trade in the Orient 1600-1800*, Minneapolis: University of Minnesota Press. Also see Kobata Atsushi 小葉田淳 (1968), *Nihon kōzanshi no kenkyū* 日本鉱山史の研究 (A Study of History of Japanese Mines), Tokyo: Iwanami shoten.

[3] Kawakatsu Heita 川勝平太 (1991), "Nihon no kōgyoka o meguru gaiatsu to Ajiakan kyōso" 日本の工業化をめぐる外圧とアジア間の競争 (External Pressure and Inter-Asian Competition Concerning Japanese Industrialization), in Hamashita Takeshi 浜下武志 and Kawakatsu Heita (eds.), *Ajia kōekiken to Nihon kōgyoka* アジア交易圏と日本工業化 (Asian Trading Zone and Japanese Industrialization), Tokyo: Libroport, pp. 157-193.

[4] For a changing conception of *sakoku*, see Arano Yasunori 荒野泰典 (1988), *Kinsei Nihon to Higashi Ajia* 近世日本と東アジア (Early Modern Japan and East Asia), Tokyo: Tokyo University Press; Ronald Toby (1984), *State and Diplomacy in Early Modern Japan: Asia in the Development of Tokugawa Bakufu*, Princeton, N. J.: Princeton University Press.

conducted within the extensive framework of Dutch colonial management. Then I will present some results of my investigation of Philipp Franz von Siebold (1796–1866), a German medical doctor who lived in Nagasaki from 1824–1830. I will focus on the geology and mineralogy carried out by him and his assistant, Heinrich Burger. The development of Japanese geology and mining after von Siebold will be reviewed in the last part of this paper.

2. Dutch Colonial Sciences and Western Sciences in Japan

The 1770s opened a new epoch both for Dutch colonial sciences and the history of sciences in Japan. The first scholarly society for the Dutch colonial sciences in Southeast Asia, the Batavian Society of Art and Sciences,[5] was established in 1778 in Batavia.[6] At the same time, interest in Western studies emerged in the 1770s in Japan, marked by the monumental publication *Kaitai shinsho* 解体新書, (A New Book of Anatomy) by Sugita Genpaku 杉田玄白 et al. in 1774.[7] The publication in the same year of *Tenchi nikyū yōhō* 天地二球用法 (Theory of Two Globes of Heaven and Earth) by Motoki Ryōei 本木良永 was also a benchmark for the Japanese adaptation of a heliocentric view of the universe. These two publications represented two different but key aspects of scientific interest in medicine and astronomy.

We see an intrinsic connection between Dutch colonial sciences and Japanese interests in Western sciences. These two historical phenomena appeared to be different events, but they had in common an orientation towards the practical application of techno-scientific knowledge. Both the Dutch and Japanese were practically oriented: both advocated systematic, applicable and useful knowledge. On the Japanese side, the pursuit of practical knowledge in medicine reinforced sound empiricism and fostered clinical medicine.[8] It is no wonder that the Dutch carried the banner of

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[5] In Dutch it is "Het Bataviaasch Genootschap van Kunsten en Wetenschappen."

[6] T. H. der Kinderen (1878), *Het Bataviaasch Genootschap van Kunsten en Wetenschappen gedurende de eerste eeuw van zijn bestaan 1778-1878* (The Batavian Society of Arts and Sciences During the First Century of its Existence, 1778-1878), Batavia: Landsdrukkerij.

[7] For Sugita's *Kaitai shinsho*, see Timon Screech, (1997), *Edo no jintai o hiraku* 江戸の人体を開く (Opening the Edo Body), Tokyo: Sakuhinsha.

[8] For general characteristics of *Rangaku*, see Grant K. Goodman (2000), *Japan and the Dutch, 1600-1853*, Richmond, Surrey (UK): Curzon Press (originally published as *Japan: the Dutch Experience*, Atlantic Highlands: Humanity Press, 1986).

emerging capitalism, while practicality and an "economic" mentality permeated their ethics.

At the same time, we see that both the Netherlands and Japan were oriented to pure scientific inquiry, not simply satisfied with plain practicality and profane profit-making. Dutch and Japanese scientists were willing to devote themselves wholeheartedly to their search for basic theoretical knowledge. Taking astronomy as an example, the focus of inquiry in Japan had long been limited to the accuracy of calendar making, but it was gradually extended to the structure of the universe and heavenly order. In medicine, it was now not only cures or clinical practices and the structure and function of the human body that was sought, but also the study of biology through a physico-chemical approach.

After Western anatomy, disciplines related to medicine, such as pharmacology, physiology, and chemistry were the targets of the curiosity of Japanese scholars of Western studies. Their pursuit was widened and spread, resulting in an overall introduction of Western sciences by 1800. An organized search in Western sciences and technology was advocated not only by intellectuals but also by political authorities beginning in the second half of the eighteenth century. Although the exact concept of "science" had not yet been identified in Japan, systematic inquiry into nature was for the first time initiated, with attempts to organize objective, empirical, and practical knowledge.

The Dutch trading station at Nagasaki was the entry point for the dissemination of Western information in Japan. Scientific books were introduced sporadically, but gradually their number increased, and the knowledge brought into Japan became systematic. Official translators (*tsūji* 通詞) who were in charge of interpreting for the Dutch and managing foreign affairs, gradually deepened their understanding of Dutch sciences, spreading scientific information, so that a *Rangaku* 蘭学 (Dutch studies) scientific community was formed.

On the Dutch side, the founders of the Batavian Society aimed at the systematic exploitation of natural and human resources in their colonies through the "most proper use of scientific knowledge."[9] The establishment of this society corresponded with the establishment of regional and local scholarly societies in the context of an enlightenment movement for the popularization of science in Holland in the middle of the eighteenth century. According to their Enlightenment agenda, the Dutch scientific interests in the East Indies were reorganized from sporadic and exotic descriptions of the nature and culture of colonies to more systematic

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[9] Marius Jacob Sirks (1915), *Indisch natuuronderzoek* (Indian Investigation of Nature), Amsterdam: Amsterdammsche boek- en steendrukkerij v/h Ellerman, Harms & co.

investigations.[10] The usefulness of "scientific" knowledge in natural exploitation was clearly recognized, though the organization of "scientific" investigation was thought to be manipulated by the political leadership. Most importantly, such a proposition was an extension of a scientific motive based on the humanitarian enlightenment of the eighteenth century. Indeed, "scientific and proper exploitation" was sometimes innocently advocated for humanitarian reasons.[11] Another stimulus came from economic motives. For instance, in 1771, Van den Heuvel argued that politically guided economic development should include a colonial perspective.[12] His argument drew the attention of the authorities, and he was subsequently appointed director of East Indies economic affairs. The Economics Department of the Holland Society[13] was established in 1777, which covered the economic affairs of the Dutch East Indies. The Governor-general, J. C. M. Radermacher, one of the active founding members of the Batavian Society, actually cooperated closely with Van den Heuvel.[14] Thus, we see a combination of three factors behind the establishment of the Batavian Society: a scientific motive based on humanitarian enlightenment, economic interests, and government support for the promotion of colonial sciences.

A classic framework proposed by G. Basalla is useful, although it represents a typical diffusionist historiography.[15] Basalla discussed a three-stage

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[10] Harry A. M. Snelders (1979), "Het Bataviaasch Genootschap van Kunsten en Wetenschappen in de periode 1778 tot 1816," *Documentatieblad Werkgroep 18e Eeuw* 1.42, pp. 62-90; Yoshida Tadashi 吉田忠 (1982), "Oranda ni okeru kagaku no taishūka to rangaku" オランダにおける科学の大衆化と蘭学 (Popularization of Science in the Netherlands and *Rangaku*), in Yoshida Tadashi (eds.), *Higashi Ajia no kagaku* 東アジアの科学 (East Asian Sciences), Tokyo: Keisō shobō, pp. 50-108.

[11] Lewis Pyenson (1989), *Empire of Reason: Exact Sciences in Indonesia 1840-1940,* Leiden: Brill.

[12] Hendrik van den Heuvel's argument was presented at a prize-winning event at the "Hollandsche Maatschappij van Wetenschappen" (Holland Society of Sciences), see also Snelders (1979), as indicated in footnote 10.

[13] In Dutch, it is "Oeconomische Tak van de Hollandsche Maatschappij."

[14] Huib J. Zuidervaart and Rob H. van Gent (2004), "A Bare Outpost of Learned European Culture on the Edge of the Jungle of Jawa: Johan Mauris Mohr (1716-1776) and the Emergence of Instrumental and Institutional Science in Dutch Colonial Indonesia," in *Isis* 95.1, pp. 1-33. Also see Andrew Goss (2011), *The Floracrats: State-sponsored Science and the Failure of the Enlightenment in Indonesia*, Madison W. I.: Wisconsin University Press, pp. 7ff.

[15] George Bassala (1967), "The Spread of Western Science," in *Science* 156, pp. 611-622.

development, proposing three overlapping phases.[16] In the period before 1816, the Dutch colonial sciences can be considered as falling under Basalla's first stage, with geography, botany and zoology being the major fields. Geological investigation was not mature enough to go beyond natural history descriptions. The journal of the Batavian Society displayed an inclination towards addressing natural history and geography, as Snelders indicates.[17] Geology was only descriptive[18] and still supplementary to natural history.[19] The geological features of Japan were therefore described from the viewpoint of natural history. One of the earliest descriptions was reported by C. P. Thunberg.[20] The first description of Japanese mineralogy was written as early as 1776, when Baron von Wurmb listed inventories of Japanese minerals within the framework of scientific research in the East Indies.[21]

After this period, as agriculture was recognized as an economic motor for the colonies, the focus narrowed down to botanical resources. Scientific interests and political-economic demand went through a phase of agrarian management of economic crops. Stamford Raffles represents this research

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[16] Bassala's three stages are: (1) an extension of geographical exploration, characterized by the survey of new territories in order to study their physical features, including their flora and fauna; (2) a stage of colonial science, characterized by the emergence of certain scientific activities with a reliance on metropolitan science and its institutions; (3) an independent scientific tradition, the final phase which would evolve when there was freedom from metropolitan science, both in research and in training of scientists.

[17] Harry A. M. Snelders (1979), see footnote 10.

[18] Reinout Willem van Bemmelen (1950), "Geschiedenis van het geologisch onderzoek in Indonesie," in *Een eeuw natuurwetenschap in Indonesie 1850-1950: Gedenkboek ter herdenking van het honderdjarig bestaan van de Koninklijke Natuurkundige Vereeniging*, Bandung, Jakarta: Koninklijke Natuurkundige Vereeniging, pp. 41-48. Also see Hendrik A. Brouwer (1929), "Geology of the Netherlands East Indies," in L. M. R. Rutten et al. (eds.), *Science in the Netherlands East Indies*, Amsterdam: De Bussy, pp. 101-125.

[19] Klaas van Berkel (1985), *In het voetspoor van Stevin*, Amsterdam: Boom Mepperl, pp. 208-213.

[20] Carl Peter Thunberg (1796), *Voyages de C. P. Thunberg au Japon*, Paris: Benoît Dandré, pp. 439-445.

[21] Friedrich Baron von Wurmb was a secretary of the Batavian Society. A list of Japanese minerals and stones reportedly collected by him is published in Bataviaasch Genootschap van Kunsten en Wetenschappen (ed.) (1786), *Verhandelingen van het Bataviaasch Genaatschap der Kunsten en Wetenschappen* 4, Batavia: Egbert Heemen, pp. 566-568. See also John MacLean (1973), "Natural Science in Japan, I: Before 1830," in *Annals of Science* 30, p. 261.

orientation.[22] He made a breakthrough in colonial research in Java, and tried to revive the then-stagnated Batavian Society. Raffles was an epoch-maker, opening Bassala's second stage. He coupled economic objectives with colonial management: scientific studies were closely associated with the promotion of useful crops and the production of commodity goods for colonial trade.

After Raffles, the Dutch colonial objective changed structurally from primary agrarian management to raw material supply, focused on commodity crops. Mineral resources were also given some attention, not only for monetary reasons but also for industrial ones. Geology began to shift from natural history, namely the Neptunian description, to micro-analysis employing physico-chemical methodology. However, research in mining drew less attention unless it involved gold and silver, mainly because mining was peripheral to colonial income; new exploration of mineral mines in overseas colonies was still not considered cost-effective.

After the French occupation, the Netherlands needed extensive structural reorganization. According to E. H. Kossmann, the Dutch tried to rescue themselves economically through investment in overseas territories, as the European market had already become saturated.[23]

In scientific programs, the leading character of this period was C. G. C. Reinwardt,[24] who proposed the establishment of the botanical garden in Buitenzorg (Bogor). This garden was eventually opened in 1817.[25] He became its first director and organized systematic research. Shortly after the garden opened, the Natural Scientific Committee for the Dutch East

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[22] Shinobu Seizaburō 信夫清三郎 (1968), *Raffuruzu den: Igirisu kindaiteki shokumin seisaku no keisei to tōyō shakai* ラッフルズ伝：イギリス近代的植民政策の形成と東洋社会 (A Biography of Raffles: The Formation of British Modern Colonial Policy and Eastern Society), Tokyo: Heibonsha; see especially pp. 174-177, 271-274 and 420-422. This book was originally published by Nihon hyōronsha in 1943.

[23] Ernst H. Kossmann (1986), *De Lage Landen 1780-1980: Twee eeuwen Nederland en België*, Amsterdam: Agon.

[24] Andreas Weber (2012), "Hybrid Ambitions: Science, Governance, and Empire in the Career of Casper G. C. Reinwardt (1773-1854)," Ph.D. thesis, Leiden University.

[25] For the botanical garden in Bogor, see Melchior Treub (1889), "Geschiedenis van's Lands Plantentuin te Buitenzorg, van 1817 tot 1844," *Mededeelingen uit's Lands Plantentuin*, VI, Batavia: Landsdrukkerij.

Indies[26] was established in 1820. This organization was supposed to be in charge of organization and policymaking for the sciences in the colony.[27]

Geological studies during this period were implemented mostly by foreign scientists, such as T. Horsfield and F. Junghuhn,[28] both of whom were employed in the Dutch East Indies.[29]

3. The Works of Von Siebold and Burger on Japanese Geology and Mining

The first Western geology brought to Japan can be found in a translation of a Dutch encyclopaedia by Noel Chomel in 1811.[30] In this work, some minerals are classified according to Neptunist geology. The Western explanation of minerals was new to the Japanese, where a mineral was considered to "generate and grow in itself while they were embedded in various rocks" according to the function of "five elements (earth, water, metal, wood and wind)" and two fundamental forces, "yin 陰 (negative)" and "yang 陽 (positive)."[31] This view was described in the classic work of

[26] In Dutch, this is "Natuurkundige Commissie voor Nederlands-Indie."

[27] For the establishment of the Natuurkundige Commissie, see Huibert Johannes Veth (1879), *Oversicht van hetgeen, in het bijzonder door Nederland, gedaan is voor de kennis der fauna van Nederlandsche lndie*, Leiden: S. C. van Doesburgh.

[28] The pan-European character of the Dutch colonial empire is worth noting. As a small country, the Netherlands made use of European scientists from various backgrounds. For example, Kaempfer was a German; Thunberg, a Swede; Horsfield, an American; Junghuhn and von Siebold were of German origin.

[29] Carel Willem Wormser (1943), *Frans Junghuhn*, Deventer: W. van Hoeve.

[30] Sugano Yō 菅野陽 (1974), "Shomeeru Orandagoban" ショメールオランダ語版 (On a Dutch Version of Chomel)," in *Nihon yōgakushi no kenkyū* 日本洋学史の研究 (Studies in Japanese History of Western Learning) 3, pp. 71-112. In this, the following articles relating to geological items were translated: Earth, Clay, Metallurgy, Agate, Amethyst, Asbest, Antimony, Ash, Alum. Noel Chomel's translation, *Kōsei shinpen* 厚生新編 (New Writings for the Public Welfare), was reprinted in 1937.

[31] For a Neo-Confucian view of earth and minerals, see Joseph Needham (1956), "Mathematics and the Sciences of the Heavens and Earth," in *Science and Civilisation in China*, vol. 3, Cambridge: Cambridge University Press. For an early history of geological sciences in Japan, see Imai Isao 今井功 (1966), *Reimeiki no Nihon chishitsugaku* 黎明期の日本地質学 (Early History of Japanese Geology), Tokyo: Rateisu (Lattice) Publisher.

Japanese geology, *Unkonshi* 雲根志, written by the erudite scholar Kiuchi Sekitei 木内石亭 in 1773.[32]

In the 1820s, a European scientist and Japanese scholars finally had an opportunity for direct exchange. Von Siebold was sent to Japan in 1824 with the assignment to promote trade through scientific research. Shortly before his dispatch, he was also appointed as a corresponding member of the Batavian Society.[33]

Von Siebold and his assistant, pharmacist Heinrich Burger (1806-1858),[34] marked a new step. They contributed to the dissemination of modern Western science and medicine. Bedside clinical education was conducted,

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[32] Doi Masatami 土井正民 (1978), *Waga kuni no jūkyu seiki ni okeru kindai chigaku shisō no denpa to sono hōga* 我が国の十九世紀における近代地質学思想の伝播とその萌芽 (Transmission and Emergence of the Philosophy of Modern Geology in Nineteenth-century Japan), Kamakura: private publication by the author.

[33] Bataviaasch Genootschap van Kunsten en Wetenschappen (ed.) (1823), *Verhandelingen van het Bataviaasch Genootschap van Kunsten en Wetenschappen* 9, Batavia: Egbert Heemen, pp. xi and xxxvii.

[34] Heinrich Burger was a "third class pharmacist" of military rank, but a very capable assistant to von Siebold. Actually his contribution to most of the collection, not only of geology and mineralogy, but also of botany and zoology, was indispensable. Owing to his humble Jewish origins, Burger has almost always been underestimated as a scientist, even by von Siebold. The late J. Richterink of Amsterdam conducted extensive research on Burger, and left his draft manuscript of Burger's biography to me when I was a graduate student at the University of Leiden in 1988. Based largely on his bequeathed study of Burger, with the addition of my own research on Burger in Japan and other historical materials, I have written two articles discussing Burger's contribution to von Siebold's research project of Japan's natural world: Togo Tsukahara, "Nihon saisho no kindaiteki yakuzaishi Hainrihhi Byurugā: Shiiboruto purojekuto no mottomo jūyō na kyōryokusha" 日本最初の近代的薬剤師ハインリッヒ・ビュルガー：シーボルト・プロジェクトの最も重要な協力者 (Heinrich Burger, the First Modern Pharmacist in Japan, and the Most Important Collaborator for the von Siebold's Project of Japanese Research), in *Nagasaki yakugakushi: Oranda watari no okusuriten: tenji mokuroku* 長崎薬学史オランダ渡りのお薬展・展示目録 (*History of Pharmacy in Nagasaki : catalogue and explanation at the occasion of Exhibition of Medicinal Materials from Holland*), Nagasaki: Nagasaki von Siebold Museum 長崎シーボルト記念館, 1999, pp. 7-15.
Also see: Togo Tsukahara, "Nihon saisho no kindaiteki yakuzaishi Hainrihhi Byurugā ni tsuite" 日本最初の近代的薬剤師ハインリッヒ・ビュルガー (Heinrich Burger, the First Modern Pharmacist in Japan), in *Dejima no Kusuri* 出島のくすり (Medicine of Dejima), Fukuoka: Kyshu University Press 九州大学出版会, 2000, pp. 23-34.

and systematic scientific instruction was delivered at their private school in Nagasaki. Their contribution is also evident with regard to geology, not only Neptunian geology, but also the introduction of chemical mineralogy being ascribed to them.

Science as conducted by von Siebold should be understood from the viewpoint of colonial sciences. Science has never been an issue of pure knowledge exchange, but was always interwoven with political contexts. Von Siebold is no exception, although he is often seen as a benefactor where the modernization of Japan is concerned.[35] Such a view can be derived only from a Whiggish interpretation of history.[36] The dual nature of his scientific activities should thus be the focal point. He disseminated medical and scientific knowledge as a benefactor while acting as a colonial scientist to exploit local resources. Using Said's argument, E. Friese regards von Siebold as an exemplification of Orientalism.[37] Another parallel is drawn by Tsuchiya[38] from the exploitation of indigenous informants in Java, which was similar to von Siebold's assignments to Japanese students.

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[35] I consider the particular way of respecting von Siebold as the benefactor of Japanese modernization, a sort of great "Sensei" for the Japanese, as a reversed expression of a Japanese inferiority complex. See Tsukahara Togo 塚原東吾 et al. (1996), "Kagakushi no sokumen kara saikentō shita Firippu Furantsu fon Shiiboruto no kagakuteki katsudō: Shokuminchi kagaku, Bēconian kagaku, Humborutian kagaku to Shiiboruto no kagakuteki katsudō to no kankei ni tsuite no shiron" 科学史の側面から再検討したフィリップ・フランツ・フォン・シーボルトの科学的活動：植民地科学、ベーコニアン科学、フンボルティアン科学とシーボルトの科学的活動との関係についての試論 (Re-examination of Scientific Activities by von Siebold from the Viewpoint of History of Science: A Discussion of the Relationship between Colonial Science, Baconian Science, Humboldtian Science and the Scientific Practice Carried out by von Siebold), in *Narutaki kiyō* 鳴滝紀要 (Bulletin for Von Siebold Museum) 6, pp. 201-244.

[36] Herbert Butterfield (1931), *The Whig Interpretation of History*, London: G. Bell. Also see id. (1950), *The Origin of Modern Science, 1300-1800*, London: G. Bell and Sons Ltd.

[37] Eberhard Friese (1983), *Philipp Franz von Siebold als früher Exponent der Ostasienwissenschaften: Ein Beitrag zur Orientalismusdiskussion und zur Geschichte der europäisch-japanischen Begegnung*, Bochum: Studienverlag Brockmeyer.

[38] Tsuchiya Kenji 土屋健治 (1984), "19 seiki Jawa bunkaron josetsu" 19 世紀ジャワ文化論序説 (Preface to the Theories of Nineteenth-century Javanese Culture), in Tsuchiya Kenji 土屋健治, and T. Shiraishi 白石隆 (eds.) (1984), *Tōnan Ajia no seiji to bunka* 東南アジアの政治と文化 (Politics and Culture in South East Asia), Tokyo: Tokyo University Press 東大出版, pp. 71-127.

3.1. Manuscript of the Unpublished *Geologica Japonica*

The geology performed by von Siebold and Burger was peripheral to their project on natural history, to which two series of voluminous publications, *Flora Japonica* and *Fauna Japonica,* were dedicated: no *Geologica Japonica* was ever published.

However, I found a series of original manuscripts on Japanese geology in the von Siebold archives at the University of Bochum, Germany.[39] The geological research was identified as having been carried out from 1824–1829, and most of the manuscripts were written by H. Burger. Their contents are as follows:

> An overall observation of physical geology with insight into "geognosy";
> Specific descriptions of individual rocks and minerals found in Japan (in the manner of "oryktognosy");
> The results of analyses of mineral water from several hot water springs;
> The mining and smelting of copper in Japan;
> The state of mineralogical studies in Japan; and
> A list of Japanese (volcanic) mountains.

From this, we can discern two characteristics. First, the primary interest was geographical description of the overall physical geology, modelled after Alexander von Humboldt's survey of "terra incognita". According to S. Cannon, von Humboldt's methodology, used by the following generation, was characterized as "Humboldtian science."[40] One of the essential features of Humboldtian science was physico-geographical observation in terms of Neptunian geology, "geognosy." Burger and von Siebold followed this methodology as well.

Second, an interest in valuable minerals is obvious. In the section on descriptive mineralogy (then called "oryktognosy" in Neptunian terms), Burger discussed sample localities, the quality and yield of metals, yearly production from specific mines, and further mining possibilities. Burger wrote a separate chapter for copper mining. As the terminology shows, this survey was carried out according to Neptunianism of the Wernerian school.

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[39] Tsukahara Togo 塚原東吾 (1990), "Nishi Doitsu Rūru daigaku (Bohhumu) ni genzon suru Shiiboruto kankei bunshochū no chishitsugakuteki chōsa kenkyū ni tsuite" 西ドイツルール大学（ボッフム）に現存するシーボルト関係文書中の地質学的調査研究について (On Historical Materials of Geological Research by von Siebold, kept in the Archive of Ruhr University, Bochum, in West Germany), in *Nichiran gakkai kaishi* 日蘭学会会誌 (Bulletin for Japan-Netherlands Institute) 15.1/29, pp. 57-77.

[40] In Walter F. Cannon (1960), "The Uniformitarian-catastrophist Debate," in *Isis* 51.1, pp. 38-55.

Around this period, the leading geological dogmas stemmed from mining practice at the Freiberg Mining Academy.[41] A. G. Werner was a professor there, and the Wernerian school of geology laid out a grand framework using the technical vocabulary of Neptunian geology. They discarded the old custom of trivial descriptions of "fossils," and instead extended their observations to "mountains" as a whole, with their meticulous stratigraphy. They made use of Agricola's works in the improvement of mining. Later, Neptunian geology faced its rival the Vulcanist school in the first half of the nineteenth century, and it was also challenged by the Hattonian controversy. Despite these challenges, Neptunian influence reached further than European metropolitan discourse assumed. For instance, in colonial geology surveys, the Neptunian method was predominant.

The Wernerian/Neptunist influence on von Siebold and Burger is evident in a list of geological and mineralogical books at von Siebold's disposal in 1823.[42] The titles related to geology include C. A. S. Hoffmann's standard work of mineralogy, and J. F. John's laboratory manual for chemical analysis.[43]

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[41] For Freiberg and Wernerian Neptunian geology, see Charles Coulston Gillispie (1960), *The Edge of Objectivity*, Princeton: Princeton University Press; Charles Coulston Gillispie (1951), *Genesis and Geology*, Boston: Harvard University Press; Reijer Hooykaas (1959), *Natural Law and Divine Miracle*, Leiden: Brill.

[42] Takeuchi Seiichi 竹内精一 (1983), "1823 nen Shiiboruto ga Ōshū to Batavia kara hakusai sase 25 nen Nagasaki de uketotta shoseki to sono go no unmei" 1823年シーボルトが欧州とバタビアから舶載させ 25 年長崎で受け取った書籍とその後の運命 (On Books that von Siebold Shipped in 1823 from Europe and Batavia, and Received in 1825 in Nagasaki, and their Destiny), in *Nichiran gakkai kaishi* 日蘭学会会誌 (Bulletin for Japan-Netherlands Institute) 8.1, pp. 1-20.

[43] Books included are:

- Christian August Siegfried Hoffmann (1811-1818), *Handbuch der Mineralogie, fortgesetzt von August Breithaupt*.

- Johann Friedrich August Breithaupt (1815), *Ueber die Aechtheit der Crystalle*.

- Abraham Gottlob Werner (1817), *Letztes Mineralsystem: Aus dessen Nachlasse auf oberbergamtliche Anordnung herausgegeben und mit Erläuterungen versehen* (hrsg. von Johann Carl Freiesleben, mit Erläuterungen von Breithaupt und Custos Kohler).

- Karl Wilhelm Gottlob Kastner (1820-1822), *Grundriss der Experimentalphysik*.

- Sigismund Friedrich Hermbstaedt (1812-1824), *Systematischer Grundriß der allgemeinen Experimentalchemie: Zum Gebrauch seiner Vorlesungen entworfen*.

- Johann Friedrich John (1808-1821), *Chemisches Laboratorium; oder Anweisung zur chemischen Analyse der Naturalien; nebst Darstellung der nöthigsten Reagenzien*.

- Georg Friedrich Parrot (1815), *Grundriß der theoretischen Physik, Thl. 1, 2, 3, and Grundriß der Physik der Erde und Geologie*.

It appears certain that von Siebold and Burger benefited from reading these works. We should note that the then newly-emerged chemical mineralogy is incorporated in the works of J. F. John and G. F. Parrot, and that Burger's analyses of mineral water used their methods.

The motives for knowing the ingredients of mineral water stemmed not only from geology, but from its therapeutic use. The application of the chemical method was, at the same time, a sign of an outgrowth from conventional natural history. Burger's chemical analysis was qualitative, yet it was systematic, employing ten different chemical reagents to determine whether a specific mineral water sample contained particular chemical elements and compounds. Chemical examination was conducted as follows:[44]

1. Add limewater (does it become cloudy?).
2. Add lead acetate (any precipitation?).
3. Add ferrous (ferric) sulphate (green?).
4. Add concentrated hydrochloric (any foaming?).
5. Add gallic acid (cloudy?).
6. Add iron prussiac kali (change in color?).
7. Add barium hydrochlorite (precipitation?).
8. Add silver nitrate (cloudy?).

Using a similar method, a Japanese *Rangaku* scholar, Udagawa Y**ō**an 宇田川榕菴 also tried some analyses of mineral water. He had some exchange with, and was certainly inspired by, von Siebold and Burger on the occasion of their visit to Edo in 1826.[45] Udagawa's contribution to the establishment of chemistry in Japan was outstanding, as represented by his extensive chemistry work, *Seimi kais***ō** 舎密開宗 (Introduction to Chemistry).[46] The analysis of mineral water was the earliest case of the transfer of chemical experimental techniques in Japan, and was performed within the framework of geological research.

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[44] For the analysis of mineral water, see Togo Tsukahara (1987), "A Study on the Beginning of Chemistry and Chemical Education in Japan," Tokyo: Tokyo Gakugei University, MA thesis.

[45] For the diary of von Siebold, and autobiography of Udagawa Y**ō**an, see Koda Masataka 幸田正孝 (1992), "Udagawa Yōan no nenpu (jo)" 宇田川榕菴の年譜（序） (Chronology of Udagawa Y**ō**an (reface)), in *Tsuyama kōsen iyō* 津山高専紀要 (Bulletin for Tsuyama Technological Highschool) 29, pp. 179-220.

[46] For *Seimi Kaisō*, see reprint edition (1975), edited, translated and commented by Minoru Tanaka 田中実 et al. His annotated translation is attached with his and other historians' extensive explanatory essays. For the conceptual analysis of Yōan's chemistry, especially his ideas on chemical affinity, see Togo Tsukahara (1993), *Affinity and Shinwa Ryoku: Introduction of Western Chemical Concepts in Early Nineteenth-century Japan*, Amsterdam: Gieben.

3.2 Interest in Useful Resources: Survey of Coal Mines and Trial Tea Transplantation to Java

Von Siebold and Burger's scientific investigations in Japan were assumed to serve the task of resource-seeking and trade promotion. Apart from the aforementioned file, I found manuscripts on the survey of useful mineral resources, such as coal in the Chikuzen 筑前 area.[47] Coal was necessary for steam-ships, and the Dutch anticipated using it for industrial development. A productive coal mine in the Chikuho 筑豊 area later supplied coal for Japan's early iron industry, the motor for Meiji Japan's industrialization.

To carry out his research on Japanese natural history and culture, von Siebold effectively used reports from the medical students at his school in Nagasaki. He ordered his students to write reports on various subjects in exchange for medical education and even for medical diplomas. His extensive use of local informants was a form of the primary exploitation of indigenous knowledge.[48]

From other manuscripts, we see their interest in commercial plants. For instance, they conducted chemical research on the soil of a tea plantation in Ureshino 嬉野.[49] This was a part of an investigation of the cultivation of Japanese tea in Java for a colonial plantation.[50] Von Siebold collected and sent several species of tea seeds and shrubs to the scientists affiliated with the botanical garden in Buitenzorg (Bogor) and members of the Batavian Society. Although Japanese tea was too weak for the Javanese climate and

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[47] For manuscripts on coal mines, see the catalogue, Vera Schmidt (1989), *Die Sieboldiana-Sammlung der Ruhr-Universität Bochum*, Wiesbaden: Harrassowitz (Veröffentlichungen des Ostasien-Instituts, 33; Acta Sieboldiana Teil 3), manuscript no. 1.379.000, p. 284. This archive is entitled "Wenige vragen betreffende de steenkolen levering van den Vorst van Tsikuzen."

[48] For the "reports" from students, see Okubo Toshiaki 大久保利謙 et al. (1938), "Monjin ga Shiiboruto ni teikyō shitaru rango ronbun no kenkyū" 門人がシーボルトに提供したる蘭語論文の研究" (Research on Dutch Language Articles Submitted to von Siebold by his Disciples), in Nichidoku Bunka Kyokai 日独文化協会編 (Japan-German Cultural Association) (ed.) (1942), *Shiiboruto kenkyū* シーボルト研究 (Studies on von Siebold), Tokyo: Iwanami Publ. 岩波書店刊, pp. 61-274.

[49] For manuscripts concerning tea cultivation, see Vera Schmidt (1989), op. cit., pp. 123-126. They were written by Theodor Friedrich Ludwig Nees von Esenbeck (1787-1837), and titled "Unterschrift unter den Notizen über verschiedene Arten des Teestrauches, u.s.w. Beschreibung des Theestrauches Thea Sinensis Linn."

[50] For tea transplantation from Japan to Jawa, see Ishiyama Yoshikazu 石山禎一 (1977), "Nihon ni okeru chaju no saibai to cha no seihō" 日本における茶樹の栽培と茶の製法 (Tea Cultivation and Production in Japan), in Ogata Tomio 緒方富雄 (ed.) (1977), *Shiiboru Nippon no kenkyū to kaisetsu* シーボルト日本の研究と解説 (Studies and Notes on Japan by von Siebold), Tokyo: Kōdansha 講談社, pp. 179-184.

the transplantation efforts were eventually aborted,[51] von Siebold was involved in this strategic investigation, comparable to feasibility studies for development projects.

3.3. The Investigation of Copper

The Sumitomo copper refinery at Osaka

On the occasion of their trip to Edo, von Siebold and Burger dropped in at the Sumitomo 住友 copper refinery.[52] According to a diary entry of von Siebold, dated June 11th of 1826, they were welcomed by a "Dutchphile" (*ranpeki* 蘭癖) merchant. They had a pleasant talk with him and conducted an observation of their copper refinery, and the merchant presented them with some "souvenirs."[53] This visit was recorded in the Sumitomo archives in a handwritten booklet, "A Note on a Visit of Red-haired People" (sixth day of the fifth month, ninth year of Bunsei 文政 reign period).[54] This

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[51] It was Taiwanese tea which actually acclimatized to Java, and was widely cultivated in colonial plantations.

[52] Von Siebold was, however, not the first to get there. Thunberg had been there in 1776. The earliest known record of a visit to the Sumitomo refinery is as early as 1690, as noted in a diary by Opperhoofd Dijkman. Also see Shoji Mitsuo 庄司三男 (1988), "Orandajin to Izumiya to Ōsaka dōfukijo" オランダ人と泉屋と大阪銅吹所 (The Dutch and Izumiya and Osaka copper refinery), in Yanai Kenji 箭内健次 (eds.), *Sakoku Nihon to kokusai kōryū (shita)* 鎖国日本と国際交流（下） (Secluded Japan and International *Exchange (2)*), Tokyo: Yoshikawa Kobunkan, pp. 55-96.

[53] The diary of von Siebold was reprinted in 1975 by Kōdansha 講談社 Press, and its Japanese translation was published in 1977-1979 by Yushōdo 雄松堂 Press.

[54] Thanks to late Takahashi Kōki 高橋孝輝 of the Tokyo University Education Research Institute, who kindly introduced me to Sumitomo Co. Ltd., I had access to the Sumitomo Archives (Shashi henshūshitsu 社史編集室) in their Tokyo Head Office. There I have seen copies of the manuscript entitled "Kōmōjin fukijo nyūrai no hikae" 紅毛人吹所入来の控, which has been reproduced for this study. This manuscript is also referred to by the several archival reports of Imai Noriko 今井典子, who worked long for Sumitomo Shushishitsu 住友修史室 (Sumitomo History Bureau). One of the earliest reports is according to Imai, the anonymously published "Shiiboruto no sankan sen Sumitomo no dōfukijo" シーボルトの参観せん住友の銅吹所 (The Sumitomo Copper Refinery Visited by von Siebold), in *Sumitomo shanaishi* 住友社内史 (Sumitomo Company Papers), 1934 issue, pp. 36-45. It was later transcribed and published again anonymously in 1980 as "Kinsei Sumitomo no fukijo no kenkyū" 近世住友の吹所の研究 (Studies on Sumitomo Copper Refinery), in *Senoku sōko* 泉屋叢考 (Bulletin of Sumitomo Archive), Osaka: Sumitomo Shushishitsu 住友修史室 (Sumitomo History Bureau), 19, pp. 34-40. Imai finally accumulated all her works related to copper and Sumitomo refinery in her

booklet shows the names of the visitors and hosts, the menu prepared to entertain them, and the gifts presented to them. The gifts included "a package of copper ores" and *Kodō zuroku* 鼓銅図録 (Illustrated Book on the Smelting of Copper), a book on copper mining and smelting, edited by the Sumitomo themselves.[55] Containing some excellent pictures and drawings, *Kodō zuroku* is a standard resource for the history of Japanese history of mining, often compared with *De re metallica* by Agricola.

Here we can see an interesting comparison between China and Japan. As Vogel notes,[56] recipients of mining knowledge like that given by *De re metallica* in China were officials, while in Japan, the knowledge-seekers

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recent book (*Kinsei Nihon no Do to Osaka Do Shonin* 近世日本の銅と大阪銅商人, Shibunkaku 思文閣: Kyoto, 2015).

[55] For *Kodō zuroku* 鼓銅図録 (Illustrated Book on the Smelting of Copper), see Nishio Keijirō 西尾銈次郎 (1943), *Nihon kōgyō shiyō* 日本鉱業史要 (Synopsis of the History of the Japanese Mining Industry), pp. 164-188. *Kodō Zuroku* has been reprinted many times, and the one by Saigusa Hirohito 三枝博人 is standard, because he has extensively annotated his reprint version (Saigusa Hiroto 三枝博音 (ed.), *Nihon Kagaku Koten Zensho* 日本科学古典全書, vol. 9, Tokyo: Asahi Publ., 1942). For a German translation see Bruno Lewin, Andreas Hauptmann, and Werner Kroker (1984), *Kodo-zuroku, "Illustrierte Abhandlung über die Verhüttung des Kupfers" [von Masuda Tsuna], 1801: Zur Geschichte der Kupfergewinnung in Japan*, Bochum: Deutsches Bergbau-Museum.

[56] Hans Ulrich Vogel (1991), "The Transfer of Mining and Smelting Technology between Asia and Europe in the Sixteenth to Early Nineteenth Century," in *Journal of the Japan-Netherlands Institute* 3, pp. 74-101. In this article, Vogel clarified the exchange of mining knowledge between Europe and Asia through the transmission of Agricola's *De re metallica* into China during the years from 1638 to 1640 by the Jesuit Johann Adam Schall von Bell. Vogel points out that the translation of *De re metallica* was dictated by the fiscal importance of the Right Vice-Minister of the Board of War, Yang Sichang 楊嗣昌 (1588-1641), who appealed for the promotion of mining, although the upsurge in mining promotion was a point of contention between late Ming military and civil officials. The latter emphasized the negative social, economic and ecological aspects of mining and stuck to the advantages of agriculture. Mining was held responsible for disturbing geomancy as well. Unlike Europe, rulers and officials in China thought mostly negatively of mining. Nevertheless, European mining literature was welcomed and consumed by a variety of people of different social strata. Since miners and smelters were mostly illiterate and occupied a low rank in the social hierarchy, the influence of such literature was, however, limited to officials and scholars. For more details see especially Pan Jixing, Hans Ulrich Vogel, and Elisabeth Theisen-Vogel (1989), "Die Übersetzung und Verbreitung von Georgius Agricolas ‚De re metallica' im China der späten Ming-Zeit (1368-1644)," in *Journal of the Economic and Social History of the Orient* 32 (2), pp. 153-202.

were entrepreneurs, such as the merchant Sumitomo. Through the efforts of these entrepreneurs, the Japanese could utilize such techniques as the liquation process (*Seigerprozess*), the separation of copper and silver by means of lead mediation.

The Collection of Rocks and Minerals: Burger's Identification in Two Nomenclature Systems

The copper ores were identified in a part of von Siebold's collection of the rocks and minerals. This collection was put together with other Japanese samples of rocks and minerals collected by von Siebold and Burger. The collection was first found and examined by Osawa in 1983 at the former Museum of Geology and Mineralogy in Leiden in the Netherlands.[57] Following Osawa's findings, I did closer research with the cooperation of Dr. C. Arps, a researcher at the museum. This collection has now been transferred to the newly reorganized Museum of Natural History.[58]

The collection was put together through at least three different acquisitions under the name of the "Von Siebold Collection." It is a collection of 107 types of rocks and minerals, including fossils, in 733 boxes. An outline of this collection is shown in Table 1, and the localities of their identified origins are shown in Maps 1 and 2. These samples are classified in boxes shown in Illustrations 1 and 2, and each specimen has some attached card or paper describing its place of origin and/or collector's name, and identification according to different systems of taxonomy. Burger's contri-

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[57] Osawa Masumi's 大沢眞澄 report first appeared in 1987 in the *Nichiran gakkai kaihō* 日蘭学会会報 (Journal for the Japan-Netherlands Institute). He also presented preliminary research results at the occasion of the annual meeting of the Japanese Society of History of Science in 1983. See also, Togo Tsukahara and Masumi Osawa (1989), "On the Siebold Collection of Crude Drugs and Related Materials from Japan," in *Bulletin of Tokyo Gakugei University* (Section IV, Mathematics and Natural Sciences) 41, pp. 41-97. Osawa finally summarized and reported his almost complete works concerning geo-sciences carried out by von Siebold and H. Burger in the following article: Osawa Masumi 大沢真澄 (2003), "Siiboruto shushu no nihonsan kobutsu/ganseki oyobi yakubutsurui hyohon narabini koko shiryo" シーボルト収集の日本産鉱物・岩石および薬物類標本ならびに考古資料 (Japanese minerals, rocks, pharmaceutics and archaeological materials collected by von Siebold), in Ishihara Tei-ichi 石山 禎一, Kutsuzawa Nobutaka 沓沢 宣賢 et al. (eds.), *Shin shiiboruto kenkyu (1) Shizenkagaku/igaku hei* 新・シーボルト研究〈1〉自然科学・医学篇 (New Studies of von Siebold (1) Natural Sciences and Medicine), Kyoto: Yasaka Publ. 八坂書房, pp. 97-113.

[58] Tagai Tokuhei 田賀井篤平 (co-authored with Ōba Hideaki 大場秀章) re-examined this collection, and reported his results in *Shiiboruto to hakubutsugaku* シーボルトと博物学 (Siebold and Natural History), Tokyo: Tomo Publ., 2010.

bution is anything but negligible, for it was Burger rather than von Siebold who collected and primarily classified most of the rocks and minerals.

In this collection, some of the copper ores were identified as having originated from the Besshi 別子 copper mine in Iyo 伊予, Sumitomo's most productive copper mine. Several pieces of slag and intermediate products of copper smelting are included, and are considered most probably to have come from the Sumitomo refinery. Two pieces of stick-shaped copper, *saodō* 棹銅, an end product of copper for export, were also found, and can be seen in Illustration 1. These can provide some references with regard to objects retrieved from the excavation of the Sumitomo refinery in Osaka.[59]

The collection is classified according to Hoffman's system with Wernerian nomenclature. Several representative specimens had cards handwritten by Burger attached, with binary nomenclature by R. Hauy (see Illustration 3). This is the most remarkable aspect of this collection: Burger's employment of these two nomenclature systems represents the historical juncture between Neptunian geology and the newly emerging chemical mineralogy.

Burger's use of Wernerian and crystallography nomenclatures shows that the earliest practice of geological science in Japan was carried out in the manner of both Neptunian geology and crystallographical/chemical mineralogy in accordance with European scientific developments. This collection also corresponds to the description of Japanese minerals in Burger's manuscript. The specimens found are listed in Table 2 with reference to Hoffman's system and Burger's works.

The gap between geology and mineralogy widened further thereafter. The development of a chemical approach in mineralogy was supported by crystallography in France and chemical mineralogy in Sweden.

It was the French development, a closer look at exterior features, that inspired the mathematical measurement of individual crystals. Rome d'Lyle and R. Hauy believed that precise and exact description would allow for better classification.[60] Their efforts resulted in the establishment of systematic crystallography. Hauy's crystallography binary nomenclature

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[59] For the excavation project of the Sumitomo refinery and related issues, see *Hisutoria* ヒストリア 176 (2001-9), feature issue for the tenth anniversary of Sumitomo (Nagahori) excavation research, and especially, Imai Noriko 今井典子 (2001), "Sumitomo dōfukijo to Ōsaka: Gijutsu to Oranda shōkancho ōsetsu o megutte" 住友銅吹所と大阪：技術とオランダ商館長応接をめぐって (Sumitomo Copper Refinery and Osaka: on Technology and Reception of the Dutch Opperhoofd), in *Hisutoria* ヒストリア 176 (2001-9), pp. 23-30.

[60] Reijer Hooykaas (1976), *Geschiedenis der Natuurwetenschappen* (History of Natural Sciences), Netherlands: Bohn, Scheltema & Holkema.

indicates the crystal structure according to the chemical composition of specific minerals.

In contrast to these French efforts, a more down-to-earth acknowledgment of the component elements of minerals led to the development of mineralogy, which was subsumed within mining practices in Sweden. The improvement of smelting techniques in mining was accomplished with the application of chemistry, especially in mid-eighteenth century Sweden. Such Swedish chemical mineralogists as Axel Fredrik Cronstedt and O. T. Bergman synthesized assay techniques into a systematic inquiry of minerals. The compilation of practical chemical techniques for mineral assay led to a breakthrough in field surveying.[61] Since it was the metal element in minerals that was sought, chemical mineralogy was essential to later mining practice. The combination of Neptunian geology and chemical mineralogy was the major scientific advantage that Burger employed in his practice in Japan.

Burger's Article on Japanese Copper

Burger wrote an article on Japanese copper based on *Kodō zuroku* 鼓銅図録 and published it in *Transactions of the Batavian Society of Art and Sciences* in 1836.[62] In it he discusses the visit to the Sumitomo copper refinery and his observations there, with citations from *Kodō zuroku*, which are identical to those found in the copy at the National Museum of Ethnography in Leiden.[63] Burger's interest in Japanese copper was motivated by commercial concerns, and this article shows the transfer of technical information from the East to the West. He outlines the copper industry in Japan, including the amount of annual production of copper at several mines, though the sources for this information are not specified

Most of the technical information is based on *Kodō zuroku*. He also provides specimens of copper ore with scientific names in both Wernerian (Dutch version) and Hauy's nomenclature, such as *Koperglas* (*cuivre sulfure*

[61] Theodore M. Porter (1981), "The Promotion of Mining and the Advancement of Science: The Chemical Revolution of Mining," in *Annals of Science* 38, pp. 543-570; David R. Oldroyd (1975), "Mineralogy and the 'Chemical Revolution,'" in *Centaurus* 19, pp. 54-71; James W Llana (1985), "A Contribution of Natural History to the Chemical Revolution in France," in *Ambix* 32.2, pp. 71-91.

[62] Heinrich Burger (1836), "Beschrijving der Japansche Kopermijnen en der Bereiding van het Koper," in *Verhandelingen van het Bataviaasch Genootschap der Kunsten en Wetenschappen* 16, pp. 1-28.

[63] "Kodō Zuroku in Rijksmuseum voor Volkenkunde" is listed in the catalogue by Lindor Serrurier (1896), *Bibliotheque Japonaise: Catalogue raisonné des livres et des manuscrits Japonais enregistrés a la bibliothèque de l'Université de Leyde* 901, Leiden, Leiden University Library, p. 204.

according to Hauy) and *bontkopererts* (*cuivre pyrite heptique* according to Hauy).

The reason for the typical red surface of Japanese copper is discussed. Although the Japanese speculated the red color to be a result of final molding in water, Burger suspected that it was a result of later treatment with high-temperature steam on the surface, in accordance with Hermbstaedt's *Experimentalchemie*.

He also points out the high content of silver in Japanese copper and the separation of it using lead in the liquation method, the *Seigerprozess* or *Zigeeren* process, which was practiced by Sumitomo. Burger wrote that the method was introduced by a Portuguese named Hakuzui around 1590, which had already been referred to in the Chinese classic *Tiangong kaiwu* 天工開物 (The Exploitation of the Works of Nature; 1637). Burger witnessed and described the detailed practices involved in this process.

The copper business provided the Sumitomo family with huge wealth, as it was their primitive means of the accumulation of capital (*ursprüngliche Akkumulation des Kapitals*). Sumitomo is a prosperous industrial-financial company even today.

Japanese copper mining and refineries attracted the attention not only of Dutch traders but also from the British. Yoshida Mitsukuni found an English article based on *Kodō zuroku* published in Canton in 1840 in the *Chinese Repository*.[64] This journal was edited by missionaries, and the article was written by Williams, who reportedly acquired *Kodō zuroku* through a friend of "Mr. Burger of Deshima." Further details concerning this, such as how and when Williams obtained *Kodō zuroku*, whether he could read Japanese, whether there were any Japanese who could translate the book for him, and how Burger and Williams met, remain to be investigated. However, it is clear that the technical procedures of Japanese copper production attracted the interest of both the Dutch and the British.

4. Geology and Mining after Von Siebold

Having been stimulated by von Siebold and Burger, various kinds of geological studies developed in Japan. For instance, Udagawa Yōan refers to the geological formation of the earth in a chapter on silica as follows: "In Europe, scholars involved in studies of geological features stipulate that

[64] *Chinese Repository* 9 (1840), pp. 86-101. See also, Yoshida Mitsukuni 吉田光邦 (1968), "*Kodō Zuroku* no eiyaku" 鼓銅図録の英訳 (English Translation of *Kodō zuroku*), in *Kagaku gijutsushi kenkyū* 科学技術史研究 (Studies of the History of Science and Technology) 22, pp. 1-5. See also Fujino Akira 藤野明 (1991), *Dō no bunkashi* 銅の文化史 (A Cultural History of Copper), Tokyo: Shinchosha.

there are three different kinds of new and old mountains: the first are called 'Original Mountains' (*Oorspronklijk Bergen*), which contain silica type stones such as granite and agate; the second are called 'Successively Formed Mountains' (*Daarnagevormde Bergen*) or 'Chalk Mountains,' which produce chalk earth such as marble and asbestos; the third are called 'Lastly Produced Mountains' (*Laast Voortgebragte Bergen*). They produce stones in the shape of animals and plants, such as petrified wood, divinely-old-cedar, dragon's bone, and fossil fish, jasper, diamond, gold, silver, copper and iron. This kind of mountain was young and formed after the big flood."[65]

Udagawa based this description on *Letters on Principles of Chemistry* (1811), a work that originated from the then up-to-date French technical education, that of the *École Polytechnique,* written by a student there, Octavius Segur, following lessons by Professors Bertholet, Fourcroy, Chaptal, and so on.[66] This exemplifies one interesting route for the filtering of European knowledge into Japan.

Mitsukuri Shōgo 箕作省吾 followed Udagara in the introduction of geology. He discussed the geological formation of the earth in a work about world geography, *Konyo zushiki* 坤輿図識 (An Overview of the Geography of the World; 1846).[67] There, he classified mountains into eight categories: 1. old mountains; 2. chalk mountains; 3. gypsum mountains; 4. salt mountains; 5. kereet [?] mountains; 6. coal mountains; 7. karamain [?] mountains; and 8. basalt mountains.

This work was influential, especially on those who feared Western military advancement, and sought knowledge on world geography. A proponent of nationalism, Yoshida Shoin 吉田松陰 scrutinized this work, and it also resonated with a military strategist, Sakuma Shōzan 佐久間象山. Inspired by it, Sakuma carried out a field survey in 1847–1849 in Shinano

[65] Udagawa Yōan (1837-1847), *Seimi kaisō*, vol. 8, ch. 160.

[66] Segur's original work is: *Brieven over de grondbeginselen der scheikunde; door* Octavius Segur, *gewezen leerling bij de Polytechnische School. Ingerigt volgens de lessen der hoogleeraren* Berthollet, Fourcroy, Chaptal, *enz* (Letters on the Fundamentals of Chemistry; by Octavius Segur, a Former Student at the Polytechnical School; Listed according to the Lessons of the High Teachers Berthollet, Fourcroy, Chaptal, etc.), 1811. On Segur's work see Togo Tsukahara (1993), *Affinity and Shinwa Ryoku*, pp. 150-151.

[67] Mitsukuri Shōgo (1821-1847) was a son-in-law of the famous *Rangakusha* (scholar of Dutch learning) Mitsukuri Genpo 箕作阮甫. *Konyo zushiki* (1846) was a leading work on world geography of the day.

信濃, and is said to have discovered useful minerals, such as copper, lead and zinc ores.[68]

His field survey was notable not only because he carried out field geology, but also because he was aware of an immediate application of such knowledge. He tried to combine the economic interest and strategic purpose of geology. As Sakuma had already advocated the colonization of Hokkaido in 1858, he practiced his interpretation of geology in a political context. He was therefore, with his interpretation on the specific relationship between knowledge and power, one of the earliest proponents of colonial science in Japan.

Changes in mining practices in the Dutch East Indies in the 1840s and 1850s was marked by changing attitudes of colonial commitment: from traders to rulers. As for agrarian management, the *cultuurstelsel* (agriculture allotment system) really began to take effect during this period.[69] There was a subsequent change in geological exploitation in accordance with this policy. The earliest administrative control of mining[70] was proclaimed in 1850 in regard to tin mines on Banka Island by *Billiton en Singkep Maatschapij*.[71] Coal and other mineral resources came to attract attention, and the potential for exploiting petroleum was openly discussed.[72] The Museum of

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[68] Sakuma's geological field notes are included in his diary entitled, "Kutsuno nikki" 沓野日記 (Kutsuno Diary; 1848), which is translated and published in Matsuura Rei 松浦玲 (ed.) (1970), *Sakuma Shōzan, Yokoi Shōnan* 佐久間象山・横井小楠 (included in a series of Nihon no meicho 日本の名著 (Japanese Masterpieces), vol. 30), Tokyo: Chuokoronsha, pp. 206-250. Sakuma was a person prone to make problematic claims of a type to play up his achievements, and no mining after this "discovery" was done. He wrote that he had gained knowledge on Western mining and geology through Dutch books, though he was dependent on others to read Dutch. In his possession were works such as: Petrus Johannes Kasteleyn (1783), *Beschouwende en werkende pharmaceutische, oeconomische en natuurkundige chemie* (Regarding the Functioning Pharmaceutical, Economical and Physical Chemistry), which includes some articles about the chemical composition of earth, rocks and minerals, but it is rather doubtful that he could have read it by himself.

[69] C. Fosseur (1988), "Tussen Daendels en Van Heutsz: Het Nederlandse bestuur op Java in de 19de eeuw" (Between Daendels and Van Heutsz: The Dutch Government on Java in the Nineteenth Century), in *Spiegel Historie* 23.10, pp. 413-419.

[70] This is called "Het Koninklijk Besluit van 1850" (Royal Decree of 1850).

[71] E. P. Wellenstein (1918), *Het indische mijnbouwvraagstuk* (The Indian Mining Problems), Gravenhage: Martinus Nijhoff.

[72] For the exploration of petroleum in the Dutch East Indies, see E. B. Wolfenden (1976), "Sources of Geological Information for S. E. Asia," *Geological Society Miscellaneous Paper* 9. Also see the recent 1912-2012 Centenary Volume: Royal

Geology in Bandung was also established as a "cathedral for scientists" in the colonies.[73]

In the 1860s and the 1870s, the institutionalization of mining in university education occurred; scientific societies were inaugurated, and specialist journals were started. For example, the *Annual Journal of the Mining Department of the Dutch East Indies*[74] was first published in 1872.[75] Then, the incubation period of the "enlightenment scientific dream" led to a direct relationship between science and politics: overseas explorers became colonial bureaucrats, and they were not "missioned scientists" any longer.[76] The romantic dreams of Humboldtians such as Raffles and von Siebold were shattered at the dawn of the institutionalization of science.

In the political turmoil of the 1850s and the 1860s in Japan, various efforts were aimed at self-protection. The visit of Perry to Japan in 1853 had a profound impact on the Japanese, leading to determined moves to build an infrastructure to make a strong nation.

Japan's industrial development was delayed in comparison with Europe. For instance, Bessemer invented a new type of furnace in 1855, and this event was considered to mark the transition from the so-called "age of iron and coal" to that of "steel."[77] On the other side of globe, the Japanese tried

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Geological and Mining Society of the Netherlands (2012) (ed.), *Dutch Earth Sciences: Development and Impact*, Den Haag: Koninklijk Nederlands Geologisch Mijnbouwkundig Genootschap (KNKMG centennial publication).

[73] The concept of the "cathedral of science" is defined in Susan Sheets-Pyenson (1988), *Cathedral of Science: The Development of Colonial Natural History Museums during the Late Nineteenth Century*, Kingston & Montreal: McGill-Queen's University Press.

[74] The original title is: *Jaarboek van het Mijnwezen in Nederland Indie*.

[75] For the institutionalization of mining sciences in the Netherlands, see Hans Stauffer (1945), "The Geology of the Netherlands Indies," in Pieter Honig and Frans Verdoorn (eds.), *Science and Scientists in the Netherlands Indies*, New York: Board for the Netherlands Indies, Surinam and Curacaop, pp. 320-335; and C. L. van Nes (1955), "De Delftse mijningenieur," in Adolph Frederik Kamp and Paul Huf (eds.), *Technische Hogeschool te Delft 1905-1955*, 's-Gravenhage: Staatsdrukkerij en Uitgeverijbedrijf, pp. 256-269.

[76] Regarding bureaucracy in Dutch colonial science, Andrew Goss argued, with his concept of "Floracrats," that the Dutch state's control in science was stronger than that of the British. See Andrew Goss (2011), *The Floracrats: State-sponsored Science and the Failure of the Enlightenment in Indonesia*, Madison: Wisconsin University Press.

[77] For the transition from "iron and coal" to "steel," see David Landes (1969), *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present*, Cambridge: Cambridge University Press.

to catch up in the race to modernization. It was also in 1855 that a reverberatory furnace was finally established in Mito 水戸 and two years later in Kamaishi, followed by Saga 佐賀 and Izu 伊豆. Local officials and engineers based their attempts on Huguenin's book (1826) on smelting in the National Iron Refinery in Liege.[78] Ohashi and Nakaoka have demonstrated that this was a successful case of Japanese endogenous industrial technology incorporating imported ideas into indigenous techniques.[79]

Coal now attracted attention for its application to iron smelting, while it had previously been used only as a fuel for steam engines. Coal mines had already attracted the attention of von Siebold, who had surveyed them as early as the 1820s. In Saga, coal mining was undertaken on the initiative of the feudal lord Nabeshima Naomasa 鍋島直正 in the latter half of the 1850s, adopting British coal mining techniques. In northern Kyushu in 1855, the Miike 三池 coal mine was opened, and the first modern shafts and galleries were sunk. Prospecting for coal started in Hokkaido as well.[80]

An engineering pioneer, Oshima Takato 大島高任, made a success of iron production with coal by creating a blast furnace to produce pig iron (containing about 4% carbon).[81] Oshima was appointed by the Tokugawa government to explore coal mines in Hokkaido. In his field survey of the Kayanuma 茅沼 mine in 1864 he applied the chemical analysis of ores. He also used explosives in mining and proposed administrative regulations similar to those still in effect today.

The situation changed drastically after the Meiji restoration in 1868. The number of foreign engineers, so-called *oyatoi* お雇い (employed), increased in mining, and the modernization process was accelerated.[82] It was not a simple diffusion of knowledge, but a process of the assimilation of Western

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[78] The original title is: Ulrich Huguenin (1826), *Het gietwezen in 's Rijks IJzer-Geschutgieterij te Luik,* 's-Gravenhage: Kloots.

[79] Ohashi Shuji 大橋周治 (1975), *Bakumatsu Meiji seitetsushi* 幕末明治製鉄史 (History of Iron Refinery from late Edo to Meiji Period), Tokyo: Agune; Nakaoka Tetsurō 中岡哲郎 (1986), "Gijutsushi no kanten kara mita Nihon no keiken" 技術史の観点から見た日本の経験 (Japanese Experience from the Viewpoint of History of Technology), in *Kindai Nihon no gijutsu to gijutsu seisaku* 近代日本の技術と技術政策 (Technology and Technology Policy in Modern Japan), Tokyo: Hatsubai Tokyo Daigaku Shuppankai, pp. 3-106.

[80] For the coal mines, see Īda Kenichi 飯田賢一 et al. (eds.) (1965), *Nihon kagaku gijutsushi taikei* 日本科学技術大系 (Series of Japanese History of Science and Technology), vol. 20.

[81] See Ohashi (1975), *Bakumatsu Meiji seitetsushi*, footnote 78.

[82] Hazel Jones (1980), *Live Machines: Hired Foreigners and Meiji Japan*, Vancouver: British Columbia University Press.

technology by indigenous Japanese. Foreign engineers were exploited for the sake of a Japanese mission to become an industrial nation, as this absorption of Western technology occurred under the umbrella of Japanese nationalism and a desire for technological independence. It was coupled with the military desire to gain hegemony over neighboring lands in Asia. This led Japan to engage in aggression; it was, in fact, the reason behind Japanese success.

5. Concluding Remarks: Network and Hybrid

Through this outline of the Dutch commitment to Asian mining resources and the Japanese development of geological sciences as a sort of by-product of this, we can see some historical conjuncture. A resonance between the two, Dutch colonial scientists and Japanese *Rangaku* scholars, was certainly amplified in this specific context of the incorporation of geology and mining in Japan. According to Pyenson, the Dutch overseas empire had a most systematic character.[83] The Japanese took advantage of this integral character of the Dutch. The Dutch sciences were not simply Dutch: for instance, it was not only Dutch scientists, as their work was carried out by pan-European scientists; the Dutch conveyed French, German, and English translations of scientific works in the Dutch language, then the *lingua franca* for the Japanese academia, as shown in the transmission of Segur's French work, then the most advanced chemical education from France, via Dutch, to Japan. Wernerian geology was of course brought via German, but it was transmitted to the Japanese in Dutch. In the infiltration of European scientific knowledge to Japan, the Japanese were extremely fortunate that Dutch was the medium; although generalization is not the historian's primary job, I would like to state that the pan-European character of the Dutch was a considerable advantage for the later development of modern science in Japan, because it was via Dutch translations that Japanese scientists became very well informed with knowledge from all over Europe, regardless of the national origins of that knowledge.

We may be able to characterize the introduction of Western geology and mining as an extensive "network of science" between the Netherlands,

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[83] Though controversial, Pyenson's characterization of Dutch colonial science is worth noting, for he provides a three dimensional model of the different natures of colonial sciences. See Lewis Pyenson (1989), "Pure Learning and Political Economy: Science and European Expansion in the Age of Imperialism," in R. P. W. Visser and J. J. M. Bos (eds.), *New Trends in the History of Science*, proceedings of conference held at the University of Utrecht, Amsterdam: Rodopi, pp. 209-278.

Dutch East India and Japan. Various levels of agents can be discerned: scientists, books, research materials and geological/mineralogical specimens. These formed multi-layered contacts and a complicated system of knowledge.

This network of knowledge can also be understood as the formation of a hybrid. Primarily, incipient geological knowledge that emerged in the form of von Siebold's collection was a hybrid of indigenous collectors and Burger's classification. On the Japanese side, the adaptation, for instance, of the chemical analysis of mineral water carried out by Udagawa Yōan represented a hybridity of knowledge and practice between the Dutch colonial practice of science and a Japanese scientist's curiosity. Burger's frequent citations from *Kodō zuroku* in his article for the journal of a Dutch colonial science society shows the employment of Japanese indigenous knowledge in mining, and it was superimposed on the metropolitan-oriented media of sciences.

During the period of the establishment of monetary independence from neighboring Asian economic systems, as argued by Kawakatsu, techno-scientific pursuits succeeded in providing instruments for the later survival of an independent Japan.[84] The various technological instruments actually allowed Japan to maintain its monetary power. In my opinion, the seemingly sudden rise of Japan as a modern industrial nation began much earlier than the Meiji restoration. It occurred because of a trickling-down of Dutch scientific material. It was, however, not a simple diffusion process, a Whiggish triumphant march of scientific rationality, but a phenomenon that took place within the politically and economically designed plot of colonial sciences and its network-building among Japanese science, and hybrid formation between indigenous knowledge and Western colonial sciences.

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[84] For Kawakatsu's argument for Japan's monetary independence, see footnote 3.

APPENDIX

Table 1. Von Siebold collection of rocks and minerals, kept at Rijksmuseum voor Geologie en Mineralogie, primary survey by Masumi Osawa in 1983, and the materials and results of Osawa's survey were directly handed to then a student of his, the author of this paper, in 1987. This table is based on Osawa's work, and later reconfirmed by Tsukahara according to his museum research in Leiden in 1987-1990. See also Tsukahara and Osawa (1989) and Osawa (2003) in the footnote 57, and Tsukahara (1990) in footnote 39.

Minerals	28 kinds	197 boxes	Quartz	72 boxes
			Chalcedony	30
			Calcite	19
Ores	20	104	Chalkopyrite	31
			Galena	15
			Sulphur	9
Sedimental Rocks	27	203	Laterite	29
			Limestone	28
			Claystone	22
Igneous Rocks	21	106	Trachyte	17
			Obsidian	16
Metamorphic Rocks	9	46	Shist	27
Fossils		72	Silicified wood etc.	72
Total	**107 kinds, in 733 boxes**			

Map 1. Sample localities of rocks and minerals collected by von Siebold and H. Burger in Japan (except Kyushu).

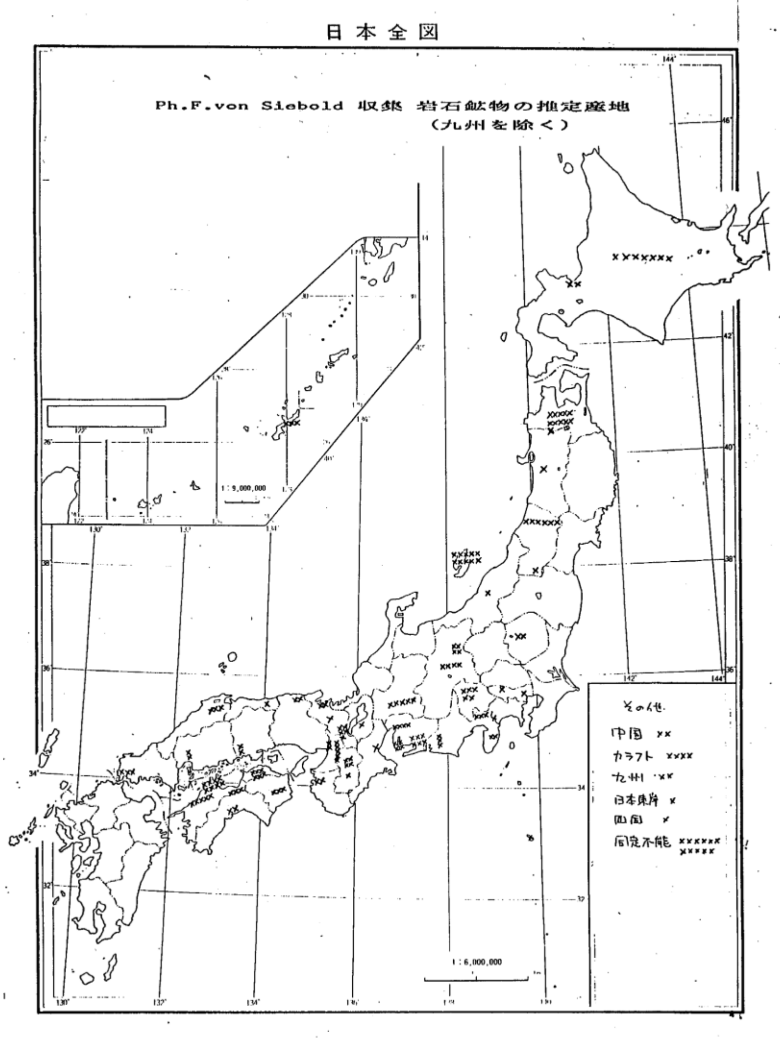

Table No.6 Map of rough sample localities except Kyushu island

Map 2. Sample localities of rocks and minerals collected by von Siebold and H. Burger in Kyushu.

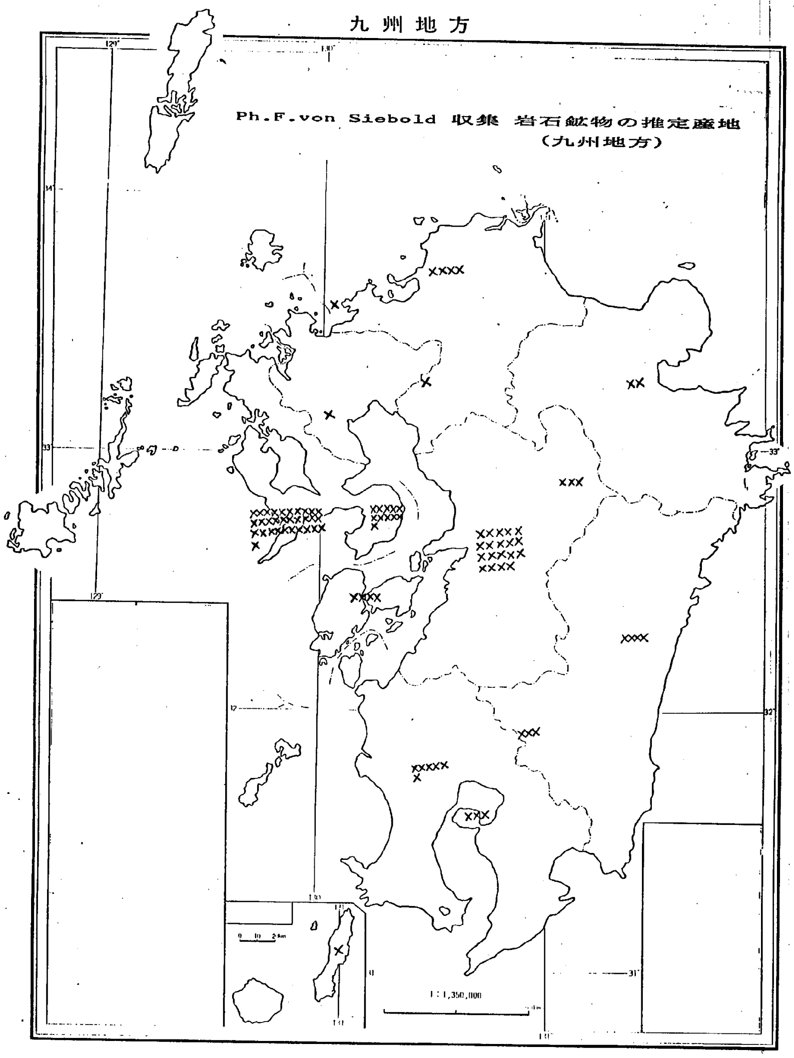

Table No.7 Map of rough sample localities of Kyusyu island

Illustration 1. A sample box of the mineral collection. Stick copper samples are shown. Photograph taken by Masumi Osawa in 1983.

Illustration 2. A sample of talc with identification cards, including the German name (large black frame) and French name with sample localities (small card). Burger's identification notes are given, both in Werner's system and Hauy's system, with the sample locality of "Unsijak, Aus der Landschaft Higo." Photograph taken by Masumi Osawa in 1983.

Illustration 3. Burger's identification notes, using Werner and Hauy's nomenclature systems. The left one gives the locality and Japanese name as "Aus der Landschaft Hiuuga" and "Aki Kwaseki" (petrified wood of Aki) respectively. The right one has "Kasiwa Kwaseki" (petrified wood of Kashiwa) for the Japanese name of the sample. Photograph taken by Masumi Osawa in 1983.

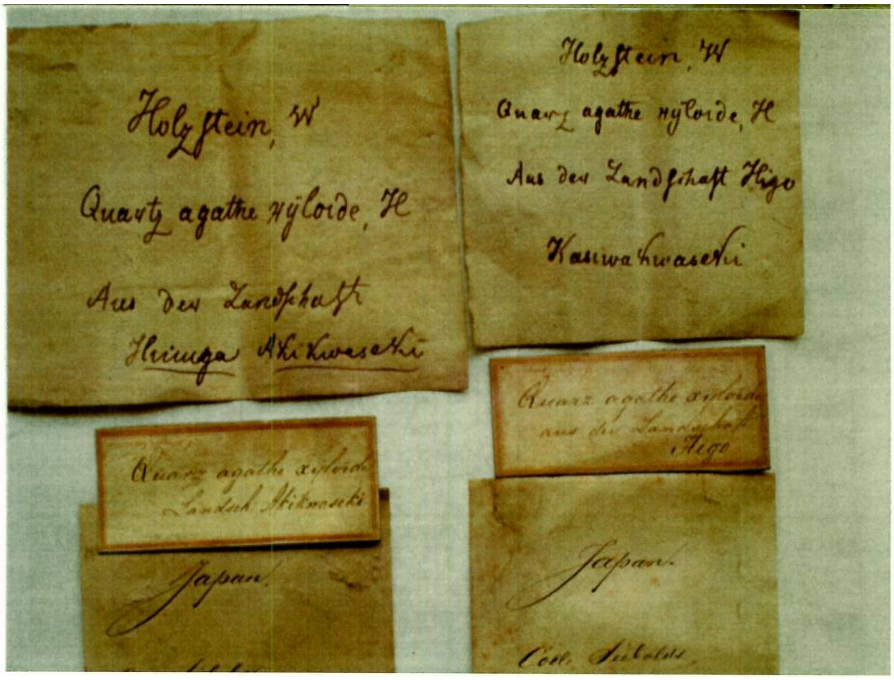

Table 2. List of von Siebold collection of rocks and minerals, in Rijksmuseum in Leiden.

In brackets [---] following Bürger's specification of the specimen is reference page in the book of Hoffmann's *Handbuch der Mineralogy* [number of volume. page.]

I. Klasse Erdige Fossilien	[I.p.353]
Kieselgeschlecht	[I.p.422]
Granat,W. Grenat,H.	[I.p.491]
Topas,W. Topaze,H.	[I.p.577]
Schörl,W. Tourmaline,H.	[I.p.626]
Quarz,W. Quartz hyalin,H,	[II.a.p.1]
Eisenkiesel,W, Quartz hyalin rubigineux,H.	[II.a.p.60]
Horzstein,W. Quarz agathe,H	[II.a.p.65-185]
Feuerstein,W. Quartz agathe pyromaque,H.	[II.a.p.83]
Kalzedon,W. Quartz agathe calcédoine,H.	[II.a.p.108]
Opal.W. Quartz resinite,H.	[II.a.p.144-156]
Jaspis,W. Quartz jaspe,H,	[II.a.p.172]
Obsidian,W. Lave vitreuse obsidienne,H.	[II.a.p.191]
Bimstein,W. Lave vitreuse pumicée,H.	[II.a.p.213]
Feldspath,W. Feld spath,H.	[II.a.p.295]
Thon Geschlecht	[II.b.p.1]
Porzellanerde,W. Feldspath argiliforme,H.	[II.b.p.10]
Schiefer Thon,W. Argile schisteuse,H.	[II.b.p.56,66]
Thonschiefer,W. Argile schisteus tabulaire,H.	[II.b.p.111]
Glimmer,W. Mica,H.	[II.b.p.115]
Hornblende,W. Amphibole,H.	[II.b.p.146]
Basalt,W. Basalte,H.	[II.b.p.162-174]
Klingstein,W. Feldspath compacte sonore,H.	[II.b.p.180]
Lava,W. Lava,H.	[II.b.p.187-213]
Talk Geschecht	[II.b.p.214]
Speckstein,W. Talc stéatite,H.	[II.b.p.236]
Bildstein,W. Talc glaphique,H.	[II.b.p.244]
Serpentin,W. Roche serpentineuse,H.	[II.b.p.255]
Talk,W. Talc,H.	[II.b.p.267]
Asbest,W. Asbeste,H.	[II.b.p.277]
Strahlstein,W. Actinote,H.	[II.b.p.293]
Kalk Geschecht	[III.a.p.1]
Kalkstein,W. Chaux carbonatée,H.	[III.a.p.2]
Kalksinter,W Chaux carbonatée cocretionée,H.	[III.a.p.32]
Erbtenstein,W. Chaux carbonatée concretionée globuliforme,H.	[III.a.p.36]
Kalktuf,W. Chaux carbonatée cocretionée .incrustante,H.	[III.a.p.40]
Rautenspath,W. Chaux carbonatée magnesifére,H.	[II.a.p.48, 57, 60]
Flussspath,W. Chaux fluatée,H.	[II.a.p.94]
Gips,W. Chaux sulfatée,H.	[III.a.p.105]
Fraueneis,W. Chaux sulfatée form:det: H.	[III.a.p.117]
Barijt Geschecht	[III.a.p.185]
Schwerfspathes,W. Barijte sulfatée,H.	[III.a.p.155]
II Klssse Salzige Fossilien	[III.a.p.208]
Kupfer und Eisenvitriol,W. Cuivre sulfaté et fer sulfaté,H.	[III.a.p.235]

III Klasse Brenliche Fossilien	[III.a.p.247]
Schwefel Geslecht	[III.a.p.252]
Vulkanischer Schwefel,W. Soufre volcanique,H.	[III.a.p.262]
Natürliche Schwefel,W. Soufre,H.	[III.a.p.252]
Erdharz Geschecht	[III.a.p.264]
Erdöl,W. Bitume liquide brun ou noirâtre,H.	[III.a.p.266]
Braunkohle,W. Houille,H.	[III.a.p.277]
Schwarzkohle,W. Houille,H.	[III.a.p.291]
Mineralische Holzkohle,W.	[Graphit Geschecht, III.a.p.319]
Resin Geschecht	[III.a.p.323]
Bernstein,W. Succin,H.	[III.a.p.324]
IV. Klasse Metallische Fossilien	[III.b.p.1]
Gold Geschlecht	[III.b.p.10]
Gediegen Gold,W. Or natif,H.	[III.b.p.10]
Quecksilber Geschlecht	[III.b.p.18]
Zinnober,W. Mercure sulfuré,H.	[III.b.p.26]
Natürlich Amalgam,W. Mercure argental,H.	[III.b.p.21]
Quecksilber Lebererz,W. Mercure sulfuré bituminifére,H.	[III.b.p.33]
Silber Geschlecht	[III.b.p.38]
Gediegen Silber,W, Argent natif,H.	[III.b.p.38]
Spiessglanz und Arseniksilber,W. Argent antimonial et Argent antimonial arsenifere,H.	[III.b.p.46,48]
Glaserz,W. Argent sulfuré,H.	[III.b.p.57]
KupferGeschlecht	[III.b.p.83]
Gediegen Kupfer,W. Cuivre natif,H.	[III.b.p.84]
Rothkupfererz,W. Cuivre oxydulé,H.	[III.b.p.89]
Kupferglas,W. Cuivre sulfuré,H.	[III.b.p.103]
Buntkupfererz,W. Cuivre pyrite hepatique,H.	[III.b.p.110]
Kupferkies,W. Cuivre pyriteux,H.	[III.b.p.113]
Fahlerz,W. Cuivre gris arsenifére,H.	[III.b.p.119]
Kupferlasur,W. Cuivre carbonatée bleu,H.	[III.b.p.134]
Malachit,W. Cuivre carboté vert,H.	[III.b.p.144]
Eisen Geschlecht	[III.b.p.186]
Schwefelkies,W. Fer sulfuré,H.	[III.b.p.190]
Magneteisenstein,W.Fer oxydulé,H.	[III.b.p.216]
Magnetischer Eisensand,W. Fer oxydulé granulair,H.	[III.b.p.223]
Eisengalnz,W. Fer oligiste,H.	[III.b.p.229]
Roth und Brauneisenocker,W. Fer oxydé pulverulente,H.	[III.b.p.254]
Eiseniere,W. Fer oxydé geodique,H.	[III.b.p.286]
Blei Geschlecht	[IV. 7) Blei]
Zinn Geschlecht	[IV. 8) Zinn]
Wissmuth Geschlecht	[IV. 9) Wismuth]
Zink Geschlecht	[IV. 10) Zink]
Blende,W. Zinc sulfuré,H.	[IV.a.p.73]
Antimon Geschlecht	[IV. 11) Antimon]
Grauspiessglanzerz,W. Antimoine sulfuré,H.	[IV.a.p.102]
Mangan Geschlecht	[IV. 13) Mangan]
Manganspath,W. Manganése oxydé carboté,H.	[IV.a.p.155]
Kobald Geschlecht	[IV. 15) Kobald]
Weisseer Speisskobalt,W. Cobalt arsenical,H.	[IV.a.p.173,174]

Arsenik Geschlecht	[IV. 16) Arsenik]
Arsenikkies, W. Fer Arsenioal, H.	[IV.a.p.211]
Rauschgelb, W. Arsenic sulfuré, H.	[IV.a.p.220]