Towards modern petrological collections

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Key words — geology, petrology, collections, selection, de-selection, de-accessioning.
Petrological collections result from sampling for academic research, for aesthetic or commercial reasons, and to document natural diversity. Selection criteria for reducing and enhancing collections include adequate documentation, potential for future use, information density, time and money invested in specimens, and spatial and financial constraints. Application of these criteria to the voluminous (*c.* 300,000 samples) rock collections of the University of Amsterdam, led to partial acquisition by the Nationaal Natuurhistorisch Museum in Leiden (Naturalis) late in 2002. Selected items included: (i) historical collections; (ii) material from former overseas domains; (iii) material from poorly accessible areas; (iv) material useful for research at the museum itself; (v) non-voluminous items with high information density (thin sections) or subjected to laboratory treatment (rock powders, mineral separates); and (vi) all samples quoted in academic dissertations.
Promotion and advertising of the newly acquired collections is expected to lead to a second life for these important academic specimens. Application of similar criteria to other museum collections will lead to partial de-accessioning, thus creating space for future acquisitions in the framework where Naturalis is increasingly regarded as the Dutch national repository of geological collections. Researchers from partner institutions will be stimulated to (de-)select their collections at the end of a project, to avoid the much higher costs of later selection by museum staff.

Contents

Introduction

Recent years have seen several alarming messages from various countries including the USA, concerning valuable natural history collections that have become increasingly threatened because of closure of museums, disposal of university collections, or extreme reduction of the number of staff members. In many cases the number of curators and technicians has dropped below the adequate level for proper collection maintenance.

At the same time, despite international efforts (e.g., Sanz & Bergan, 2002), universities are becoming less interested in maintaining large natural history collections, focussing on what they regard as their core business, i.e., teaching, requiring a small basic collection, and research, needing mainly temporary work collections. Whereas this may be cost-effective on the short term, it is likely to threaten the international knowledge base on natural diversity and natural processes, with potentially negative spin-off in many fields of human endeavour, including agriculture and ecosystem research.

In The Netherlands, awareness of the importance of natural history is still at a high level (e.g., Ministry of Health, Welfare and Cultural Affairs, 1992), but several factors have contributed to a situation that is not ideal. Firstly, the Ministry of Education, Culture and Sciences (OC&W) has a structure in which Culture, including academic heritage, is separated from Education and Sciences. This leads to a situation where universities (Education and Sciences) are not, or no longer, funded for maintaining large natural history collections, whereas museums (Culture) are not, or only insignificantly, funded for doing research. Secondly, a large restructuring has occurred in the Earth sciences in the late 1970s to early 1980s, leading to closure of Earth science departments at the universities of Leiden (UvL) and Amsterdam (UvA), and strong reduction in capacity in Groningen, Delft and Wageningen. As a result, many collections were kept at the lowest level of maintenance and were unavailable to the scientific community (see de Clercq, 2004, for more details). Collections of UvL became part of the Nationaal Natuurhistorisch Museum Naturalis in Leiden, which started as a merger between the geological and zoological museums in this city (van der Land, 2001).

Naturalis is increasingly considered as the national repository for natural history collections in The Netherlands. In view of this national role, Naturalis was asked to acquire a large selection of the UvA material, mainly palaeontological and petrological specimens. In this paper, I discuss our petrological collection philosophy, starting with a general outline about sampling, selection and de-selection. Although I realize that some potentially valuable material may have been lost in the process, I am confident that the transparent procedure has led to increased quality of the collections, which are now more fit to be re-used by future generations of Earth scientists. The criteria listed may also be applicable to petrological collections in other natural history museums. Modernizing our geology collections may be an important step in increasing the awareness of the unique natural history of our planet, a history largely stored in museum collections.

Why and how do petrologists collect?

In this paper, I loosely consider petrology in the broad sense as the field of science concerned with consolidated rocks. Geological specializations falling under this definition include metamorphic and magmatic petrology, volcanology, structural geology, and to a lesser extent sedimentology, where involved with lithified sedimentary rocks, i.e., 'hard' rocks with relatively low porosity. Excluded are palaeontology and 'soft' rock sedimentology, mineralogy and gemmology.

Petrological specimens *sensu lato* are generally collected within the framework of fieldwork in a specific research area or by means of drilling. Some of the main reasons for collecting are (see also Sola, 1999):

1. for academic research, distinguishing the following phases:
   • preparatory research (pilot studies)
   • main research phase, often leading to Ph.D. theses
   • complementary sampling, rounding off the research project;
2. to document diversity:
   • special phenomena (e.g., meteorites, rare mineral associations)
   • geological overview of an (excursion) area or country
   • for educational purposes;
3. for aesthetic or commercial reasons:
   • exhibition specimens
   • dimension stone, ornamental stone
   • ores, including industrial minerals.

Which material deserves to be kept ... and for how long?

Material that obviously must be kept for future generations includes rare items such as holotypes and figured specimens; objects providing evidence for maps, dissertations, etc.; material from sites of dramatically reduced accessibility; objects, including instruments, highlighting the history of scientific thinking; and valuable exhibition or commercial material such as gems, meteorites, etc. (see contributions in Nudds & Pettitt, 1997). It is also important to consider the usefulness of material in the case of future theoretical or analytical advances. The three types of collections mentioned in the previous section are discussed below, particularly regarding their future potential in academic or other collections.

Academic collections — Material collected for research obviously must be kept in an integral way during the main stage of active research, i.e., temporarily. During research it is commonly hard or impossible to predict whether a sample will ever be used again, because research questions, themes and methods may change with time. Material from pilot studies is often of a lower quality, because it is common practice during reconnaissance fieldwork to collect as much material as possible from as many places as possible to obtain a first overview. During the main research stage, a major part of this material commonly turns out to be uninteresting. Although keeping in mind that research questions may change, it is recommendable to de-select and dispose of some of this material already during the active research phase, if it does not come from unique localities.

It is equally common that additional sampling is carried out during the waning stages of a project, e.g., during the last field season. Such samples may have been collected with very clear research objectives in mind, but there may be little time left to investigate them properly, especially in the case of high researcher mobility. Hence, keeping them may only be useful if there is good reason to expect further research in the near future.

One process that ought to be applied to all types of research material is partial deselection at the end of the active project, employing clear, defendable and controllable criteria (see below). Only after significant reduction and when accompanied by sufficient documentation is it useful to store material for future researchers.

The potential to do modern research on old collections may be illustrated by a brief summary of some new theories in the Earth sciences: modern plate tectonics since the late 1960s (e.g., LePichon, 1968); pressure-temperature paths since the early 1960s (Schuiling, 1963); discovery of ultra-high temperature metamorphism in continental crustal rocks (e.g., East Antarctica, India) since the late 1960s (Dallwitz, 1968); discovery of ultra-high pressure metamorphism in continental crustal rocks (e.g., Alps, Norwegian Caledonides, Tien Shan) since the 1980s (Chopin, 1984); and theories involving extensional collapse after collision, mantle lithosphere delamination, etc. (e.g., Betic Cordillera/Alborán, Aegean), also since the 1980s (Bird & Baumgardner, 1981). In addition, technical advances allow analysis of major and trace elements as well as radiogenic and stable isotopes on increasingly smaller samples, down to the micron-scale (e.g., ion microprobe, Laser Ablation ICP-MS), requiring much smaller fragments for relevant scientific output. Examples are research on presolar particles in meteorites (e.g., Clayton, 1974), and U-Pb ion microprobe geochronology on zircon and monazite microdomains (e.g., Froude *et al*., 1983). Such new theories and techniques can be applied to properly maintained rock collections.

Material documenting diversity — This material may be selected on the basis of historical aspects, uniqueness (inherent or because of poor accessibility and deteriorating outcrop conditions), representativity (reference material), exhibition value and future research potential. Collections frequently used for student education, commonly systematic collections, should be stored at the universities, rather than at national depots such as Naturalis. However, if certain fields of expertise are being discontinued at a department, a common event in times of budget cuts, it would be natural to transfer related educational collections to a national museum. Large museums such as Naturalis commonly have an educational sector devoted to the non-specialized public, and staff members regularly teach in other institutions.

Excursion collections, a special class of educational collections, may remain of interest if natural history excursions to related areas are being organized regularly and if providing background information is a key element of such excursions. So-called country collections can be valuable under the same conditions as excursion collections, but also in the case of countries or areas that are poorly accessible for geographical (e.g., Greenland, Tibet) or political (e.g., Afghanistan, Iraq) reasons. Another example of inaccessibility is when outcrop conditions have deteriorated considerably several years after sampling of a road section, inhibiting future sampling along the same section. Similarly, tunnels, abandoned mines and wells can rarely ever be resampled. Meteorites are also rare enough to keep under all cicumstances, even when considering the large number of them found in hot and cold deserts in recent years.

Aesthetic and commercial material — Material collected for aesthetic reasons will generally be useful for exhibitions or possible sale, but generally has a relatively small total volume. Bulk material from ore exploration and mines is commonly of poor aesthetic value and can largely be removed. A small part can be kept for its educational aspect, documenting how raw materials can be detected. Well-developed minerals are, of course, always highly appreciated.

Discussion — The Ministry of Health, Welfare and Cultural Affairs (WVC, now merged in OC&W) mentioned in its Rescue Plan for Cultural Heritage (Ministry of Health, Welfare and Cultural Affairs, 1990) that material collected (bought) by a previous director (i.e., curator) may be kept for historical reasons, but this does not seem very useful in petrological collections. The motives behind collecting in geology/petrology are generally less personal and less culture and time dependent. Quality demands, however, are among the few aspects that have changed over the years. For example, the old Indonesian collections, collected by the Dutch before Wold War II, contain a large number of river boulders, whereas present-day collecting has a strong emphasis on *in situ* sampling, preferably even oriented.

Another difference with the world of art is that untreated samples may have high scientific value. For example, material collected during expeditions to poorly accessible areas may not have been investigated by the collectors, but could potentially represent the only specimens for future research into those areas.

The potential loss of diversity for future generations plays a much smaller role than in zoology. Although some unique exposures have been lost, such as by concrete covering or by uncontrolled collecting, new exposures are constantly being produced, e.g., new road cuts in mountainous areas or badlands in semi-arid zones. There may also be a limit to what we should regard as 'irreplaceable' and it seems important to guide our thinking not by personal scientific preference, but by objective (or at least inter-subjective) criteria.

From collecting to keeping: selection criteria

There are many ways to selectively shrink collections and simultaneously enhance their quality. Below I will systematically discuss a number of selection criteria, first in general, then applied to rock collections recently acquired by Naturalis. Some of these criteria are based on boundary constraints that are non-scientific, but have major influence on the implementation of the preferred strategy, such as spatial and financial constraints.

Selection criteria

I. Quality demands — The following is a list of minimum quality demands that ought to be met for petrological material (see also contributions in Nudds & Pettitt, 1997):

1. Good documentation (e.g., Doughty, 1992) of all objects with the exception of unique specimens with inherent value:
   - collector (name, institute, year, project),
   - sample map of the project area and sample list, preferably with coordinates,
   - clear sample numbers and/or labels.
2. Considerable variation, little doubling (e.g., not 10 samples of a homogeneous granite).
3. Dissertation or other publications.

   The third demand can be loosened if unpublished, yet high-quality documentation exists, e.g., when a dissertation has not been completed. One may also ponder the issue of what kind of publication is deemed good enough; is an excursion guide or a paper in a low-ranking, local journal sufficient, or does it have to be a journal mentioned in the Citation Index or GeoRef?

II. Spatial constraints — Most museums have space problems and Naturalis is no exception. We have a large collection tower and an additional depot (Raamsteeg) in the centre of Leiden, but the recent acquisition of collections from various universities (Technical University of Delft = TUD, UvA, University of Utrecht) has almost completely filled any prior empty space in the two buildings. Spatial problems will always remain, unless we have the courage to adopt a new collection philosophy and implement new methods for selecting and de-selecting. Using additional buildings, e.g., building a second tower at Naturalis, could provide temporary relief, but if the collection philosophy is not changed drastically, it will only be a matter of years before the voids are filled again (see, e.g., Sola, 1999), in the very same manner that new highways do not lead to less traffic jams on the long run. It also seems unfair to future scientists if criteria for keeping objects from their collections are more severe than those for old collections.

Early in 2001, when the practical part of the Geological Heritage project started (see de Clercq, 2004), the rock collections at Naturalis were located in *c*. 275 racks distributed over four main compartments in the collection tower. At 32 carton boxes per rack, this means 8800 boxes, containing *c*. 220,000 rock samples. The rooms were fully occupied by standing racks and there was no space for additional acquisitions. The Raamsteeg depot held *c*. 480 boxes (*c*. 12,000 samples), mainly sediments, and had space for another 2000 boxes, although not stored in an ideal way. Space at the Raamsteeg was soon to be filled by major acquistions from the TUD later that year.

In view of the size of the anticipated acquisitions, it was decided that more space could be created by purchasing movable containers for the collection tower, similar to when the Jongmans collection was acquired in 1996-1997 (see van Waveren, 2004). Doing so would increase the storage capacity by *c*. 65 racks (*c*. 2000 boxes) and thus enhance the efficiency of the building. Movable containers were not considered useful for the Raamsteeg depot, because it is an expensive investment and the future destination of the historical building remains uncertain.

III. Representative rock samples — By contrast to, for example, art objects and zoological and palaeontological material, petrological material shows a certain degree of homogeneity due to the operation of physico-chemical processes. This homogeneity is, however, dependent of the scale of observation. For example, granites may be heterogeneous at mm- to cm-scale, but homogeneous at dm- to m-scale. The scale of homogeneity strongly depends on grain size; slates and schists (fine-grained) may be homogeneous at cm-scale, whereas granulites (coarse-grained) are commonly homogeneous at dm-scale or larger. Hence, every rock type has a corresponding representative rock sample. The same applies to bulk (geo)chemical analyses; only an analysis of a representative sample is useful, unless small-scale processes are being investigated. Sediments and tectonites (rocks displaying deformational phenomena) may locally require more material, when important structures (cross-bedding, folds) occur at dm-scale.

For fine-grained rocks (volcanites, schists) a small block ('chip') of 5 2 3 2 1 cm from which thin sections could be cut may be sufficient, especially in the case of purely scientific material of low uniqueness that is unsuitable for exhibitions. Hence, wherever such rock chips and thin sections are available, the remaining material can, in principle, be removed, creating significant reductions in the space occupied. Coarse-grained rocks require more material, but one could store a slice rather than an original bulky sample. For exposable material the opposite is often true; large blocks of several hundred kilogrammes (e.g., graphite from Sri Lanka, banded iron formation from Greenland, meteorite from Canyon Diablo) make a much larger impact on the general public than tiny specimens.

IV. Financial constraints — Storage of petrological collections in the Naturalis collection tower costs *c.* € 200 per m^2 per year, corresponding to *c.* € 150 per rack (60 2 120 cm floor dimensions), i.e., *c.* € 5 per box per year, excluding personnel costs (total costs may be as high as € 500 per m^2 per year). To this one has to add the costs of moving, digital registration and incidental conservation measures. As many collections result from projects that have either been terminated or are in their final stages (see next section), one can anticipate a fairly low average level of usage in the coming years, allowing the question to be raised whether the high cost for storage is warranted, and whether constant accessibility is required (cf. collection accessibility at the Smithsonian in Washington). Reducing accessibility, i.e., increasing the time needed to make specimens available on request, could lower the storage costs.

V. Potential for future use — Graphs of the cumulative number of publications over a period of 40 years (Fig. 1) by Dutch Earth scientists in three project areas (Betic Cordillera, southern Spain; Galicia, northwestern Spain; Bergslagen, central Sweden)

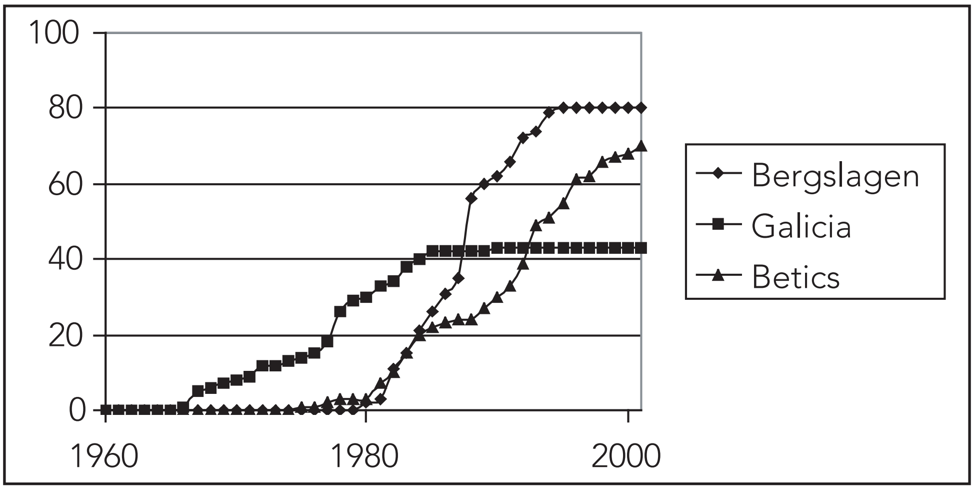

Fig. 1. Cumulative number of publications produced by Dutch Earth scientists in the course of three major, regional research projects in Europe. All three examples show an initial phase of pilot studies and low production, followed by a main phase, and are terminated by occasional papers after the active project period has expired. Note that the Betic Cordillera project keeps being productive and may settle at similar output as the Bergslagen project. Source: GeoRef (SilverPlatter WinSPIRS®, v. 4.01).

give some interesting results. All graphs show an S-shape that fits the three phases of research (see above): (i) slow start with sporadic publications; (ii) main phase with steep increase in the number publications; and (iii) slow finish, again with sporadic publications. It is also clear that the Bergslagen and Galicia projects have been terminated completely, whereas the Betic project still leads to a few publications per year, although it seems to have reached the last phase. The Bergslagen project has led to roughly twice the amount of publications as the Galicia project. The final number of publications on the Betic Cordillera may settle at a comparable level as that of the Bergslagen project. This does not necessarily reflect quality, because some projects may put more emphasis on producing monographs and geological maps.

Discussion — No hard predictions for potential future use of the collections can be derived from the graphs in Fig. 1, because research themes and methods can differ fundamentally in the future. For example, the discovery of majoritic garnet in garnet peridotites from the central Alps (Alpe Arami) has triggered renewed interest in the Alpe Arami collection of Naturalis, which is now on loan to Utrecht University. Importantly, funding associations are rarely willing to fund long-lasting projects, unless a fundamentally new scientific question is being formulated, and there is increasing pressure to address thematic rather than regional issues. We can therefore assume that only a small part of these collections will be re-used in near-future research, but we cannot with any degree of certainty predict which part. This futurological dilemma has led to the cautionary (or 'no regret') principle in museum collections (e.g., Krikken, 1997), stipulating that objects should not be removed permanently when their future use cannot be excluded.

In view of the uncertainty to predict exactly which rock sample will later turn out to be important for research, we need to develop other criteria for (de-)selection and storage of scientific material, based on uniqueness, representativity, connections to existing publications, etc. Possibly one of the most important issues is the ability to check past research, to verify or reject past conclusions, and to do some additional research, including analyses, that directly builds on the old material. Rendering the material accessible is crucial to provide potential users a quick overview of past research and to check the evidence. In my view, this is possible with a reduced number of rock samples, that are representative at the regional and thematic levels, and have a representative size.

Based on this discussion, we adopted a collection philosophy for petrological collections at Naturalis, which strongly emphasizes the following aspects: information density (e.g., thin sections, rock chips); energy and money invested in objects (e.g., thin sections: *c.* € 35 each; mineral separates: up to € 100 per sample); estimated scientific re-usability; quality of documentation; accessibility of source areas (e.g., mountains, drill-cores, tunnels); and spectacular specimens for exhibitions. This philosophy was first applied to the rock collections from the UvA, that were about to be redistributed in 2002 (see below). As for the above mentioned five criteria, the priority used was: II > I > III + V. This order is quite logical, because available storage space (II; and, to a minor extent, finances) determines how many (and what size) samples can be acquired (III); and the quality of documentation (I) determines whether specimens can be re-used or not (V).

UvA collections: analysis of selection methods and criteria

The Department of Geology at the (City) University of Amsterdam (formerly GUA, now UvA) was closed in the eighties and a number of staff members continued their careers at the Free University of Amsterdam (VU; see de Clercq, 2004). For many years, the rock and thin section collections (*c*. 13,200 boxes, divided over > 500 subcollections) remained largely at the original UvA depot at Roeterseiland. An important part of the collections (*c*. 2600 boxes, notably collections from Timor, mainly fossils) were on permanent loan to the Geological Museum of Artis, the Amsterdam Zoo, and still remain there (see below). When it was discovered that the depot at Roeterseiland showed severe contamination by asbestos, the boxes were cleaned and transferred to a temporary depot in the nothern outskirts of Amsterdam, which had to be evacuated by the end of 2002. As a result, the UvA collections formed the largest part of the so-called threatened Earth science collections in The Netherlands (see de Clercq, 2004).

Since it was neither physically possible nor useful to try and acquire all subcollections, we adopted three (de-)selection methods at Naturalis (see below), each with its own criteria, to ensure that a significant fraction of the academic geological heritage (see, e.g., Timberlake, 1997) would remain available and accessible for later generations of Earth scientists. Each method is based on assumptions that will be clarified and discussed in the following subsections. In addition, each method has specific consequences for storage facilities, finances and future accessibility of the material.

Selection on the basis of researcher status — This method is based on the premise that material collected within the framework of a Ph.D. dissertation has a higher quality than objects collected by students during their mapping or M.Sc. research projects. Staff collections, collected by university professors and lecturers, were also anticipated to meet relatively high standards, although the related documention later turned out to be disappointing. The order of selection could then be (if relevant documentation exists): 'historical' collections (mainly Indonesian material collected prior to WW II); dissertation collections; staff collections; excursion and country collections; and student collections.

The historical collections of the UvA, including areas relevant to the Dutch territorial history (Indonesia, Surinam, the Caribbean), comprised *c*. 1750 boxes. The Geological Museum at Artis housed about 950 of them (mainly the so-called Timor collection), so *c*. 800 remained. The dissertation collections (beside the historical collections, which included some pre-World War II dissertations) consisted of *c*. 3700 boxes, and the reasonably well documented staff, excursion and country collections amounted to *c*. 2200. Therefore, the total reached *c*. 6700 boxes, with an estimated 170,000 objects, requiring *c*. 220 storage racks. About 70% of them consisted of rocks (sedimentary and petrological material) and *c*. 30% of fossil-bearing samples, where each fossil-bearing sample may easily contain tens to hundreds of fossils, and even thousands in the case of micro-fossils. The total amount was thus well beyond the upper capacity limit of Naturalis (see above). If the final acquisition were narrowed down to historical collections and dissertation collections, there would still be 4500 boxes (*c*. 150 racks) left. Dissertation collections from the Betic Cordillera project (southern Spain) alone already amounted to 2400 boxes (*c*. 80 racks).

In view of space limitations, at least all excursion collections, country collections, student collections and most staff collections would have to be rejected, possibly with the exception of a few that would fit well into current and anticipated research programmes at the museum. From a practical point of view, this would have been an easy solution, where selection could have taken place entirely at the UvA depot, before moving the chosen ones to Naturalis. Storage costs would be *c*. € 22,500 per year, excluding personnel costs. This option was considered possible in the case of sufficient state funding, but the complete rejection of some important collections (e.g., Tanzania, Andes) was seen as a major drawback.

Selection on the basis of publications — This method is based on the notion that it is useful to keep material as testimonies of past publications, allowing future researchers the possibility to view and check old pieces of evidence. This is important, because theories and research methods may change with time, which sometimes calls for renewed testing of past researchers' conclusions using their own collections. It may be useful in this context to distinguish between dissertations (commonly monographs) and publications in scientific journals. Dissertations generally provide a more complete picture, with more documentation, of the results obtained on the basis of research in a specific area or on a specific theme.

The order of selection could then be (if relevant documentation exists): historical collections; dissertation collections; staff collections that have led to publications; and student collections that have led to publications. Excursion and country collections have rarely led to (serious) publications, except for local excursion guides. The major distinction with the previous section is that less weight is attached to (apparent) research status and more to publication output.

Similar to above, the integral acquisition of historical and dissertation collections would already amount to *c*. 4500 boxes. We investigated key publications coupled to staff and student collections via GeoRef (SilverPlatter WinSPIRS®, v. 4.01) and estimated the aditional subcollections required at *c*. 2000 boxes. The total reached, *c*. 6500 boxes, is similar as in the previous section, requiring similar storage space and similar annual storage costs.

Selection on the basis of information density – The basis for this method is to maximize the information density per unit space, thus either saving space and storage costs or maximizing the total amount of information that can be stored in the existing storage facilities. In this option there is no attempt to gather all existing objects and information of a given rock collection, nor to keep all information related to publications (e.g., Ph.D. dissertations). Instead, the starting point is a collection of key information carriers, i.e., objects and documentation that give an efficient overview of a certain area or theme. The emphasis for reuse of the collections thus lies on their potential for pilot studies, e.g., in the early phases of future research projects, rather than on a full record of the past. It may thus be seen as a more foreward-looking approach. Future scientists are given the opportunity to study existing material before designing plans for subsequent sampling in relation to their specific research themes. This approach seems far more cost-efficient than the other selection methods.

It has been remarked above that a representative rock sample for fine-grained petrological material may be a 'chip' of 5 2 3 2 1 cm. Extrapolating this line of thought leads to the following strategy:

1. Keep all thin sections and other treated material (powders, analyses) for each publication (incl. dissertations, M.Sc. theses, excursion guides, etc.).
2. If available, also keep all rock chips.
3. Keep all documentation (theses, publications, field books, maps, etc.).
4. Select those samples that have been mentioned in the publications.
5. Add representative, oriented and/or aesthetic/historical specimens (categories A and B: Krikken, 1997).

This approach emphasizes material which has been treated in various ways (sawing and thin sectioning, crushing, mineral separation), i.e., the specimens in which most energy and money has been invested. This leads to a strongly reduced number of petrological samples, simplifying access of the material for future use and reducing storage space and costs.

Final choices and implementation — The final choices made by Naturalis were based on a combination of the following criteria:

1. Category A collections (historical and/or rare: Krikken, 1997) were to be acquired on an integral basis.
2. Emphasis should be on high information density (thin sections, rock powders, etc.).
3. All samples quoted in Ph.D. dissertations were considered as evidence and thus geological heritage. The potential for future research was also considered highest for Ph.D. material.
4. Student collections were only considered if they fitted into Naturalis research programmes.
5. Many staff and excursion collections were rejected because of the poor level of documentation.
6. Poor accessibility of collection sites mainly applied to closed mines in the Bergslagen district, but they were considered appropriately covered by collections in Sweden.
7. Special phenomena and samples valuable for exhibitions would have been selected, but were hardly present.

The following steps were proposed to, and approved and funded by, the Mondriaan Foundation:

1. Replacement of old racks by movable containers in 50% of one large storage room to increase storage capacity.
2. Selection and repacking of most rock samples in Amsterdam, prior to disinfecting and moving to Leiden.
3. Final selection of some collections (Himalayas, Andes, Tanzania) in Naturalis at a later stage.
4. Digital registration at Naturalis, followed by active advertisement of collection presence and promotion of their re-use.

For practical purposes, three selection codes were employed for the communication with those doing the physical separation. Code A meant that all material was to be transferred to Naturalis, preferably after repacking. Some selection would possibly still be required later. This mainly applied to collections from Indonesia, Surinam, the Caribbean, the Himalayas, the Andes and Tanzania. Code B indicated all thin sections with rock chips and documentation; and all samples mentioned in Ph.D. dissertations (monographs) or related publications, for which lists were made by Naturalis technicians. Special samples, if present, could be added. Code C meant only thin sections with rock chips and documentation. No rock samples were selected in this case, which mainly applied to staff and student collections.

Fig. 2. Collection mobility formalized: signing the transfer of geological collections. The secretary of the University of Amsterdam (Mr. Bleijerveld, centre) is flanked by representatives of Naturalis (Mr. Van der Weiden), Natuurhistorisch Museum Maastricht (Mrs. Dingemans), Geological Research and Development Centre in Bandung, Indonesië (Mr. Dwiyanto) and Natuurmuseum Nijmegen (Mr. Styns).

Formalizing collection mobility — On 28th April 2003, the Dutch Academic Heritage Foundation (SAE) organized a symposium on the theme "Keeping to be used", in collaboration with Naturalis, the Library of UvL and the Scaliger Institute, also part of UvL. After the symposium, those rock collections of the University of Amsterdam that had been selected were formally transferred to their new owners/keepers (Fig. 2). This sealed some 20 years of academic history, during which the UvA geological collections had remained orphaned in poorly accessible depots, and paved the way for a second life of these collections, nicely fitting the theme of the symposium.

Naturalis highlights before and after the UvA acquisition

Besides extensive zoological collections, Naturalis currently houses > 1,100,000 fossil samples, > 400,000 rock samples, > 40,000 mineral specimens, *c*. 180,000 thin sections, and related documentation such as dissertations, research papers, reports, field note books, maps, photos and analytical data. Most of these numbers represent minimum estimates, as many individual samples (registration units) may contain tens or hundreds of fossils or crystals.

Some collection highlights at Naturalis are: the Staring collection, material related to the first geological map of the Netherlands; the Von Siebold collection, related to the first geological research in Japan (VOC); the Dubois collection, comprising *Homo erectus* and related material (part of the World Palaeontological Collections: Cleevely, 1983); the Schürmann collection, mainly Precambrian rocks of North Africa (Zwaan, 1994); the Jongmans collection, amongst others fossil plants from abandoned Dutch coal mines (van Waveren, 2004); the Zandstra reference collection of erratic boulders; and the King William I gem collection, invaluable as a reference set of natural gems. For an overview of the history of the geological collections, see Winkler Prins (2004).

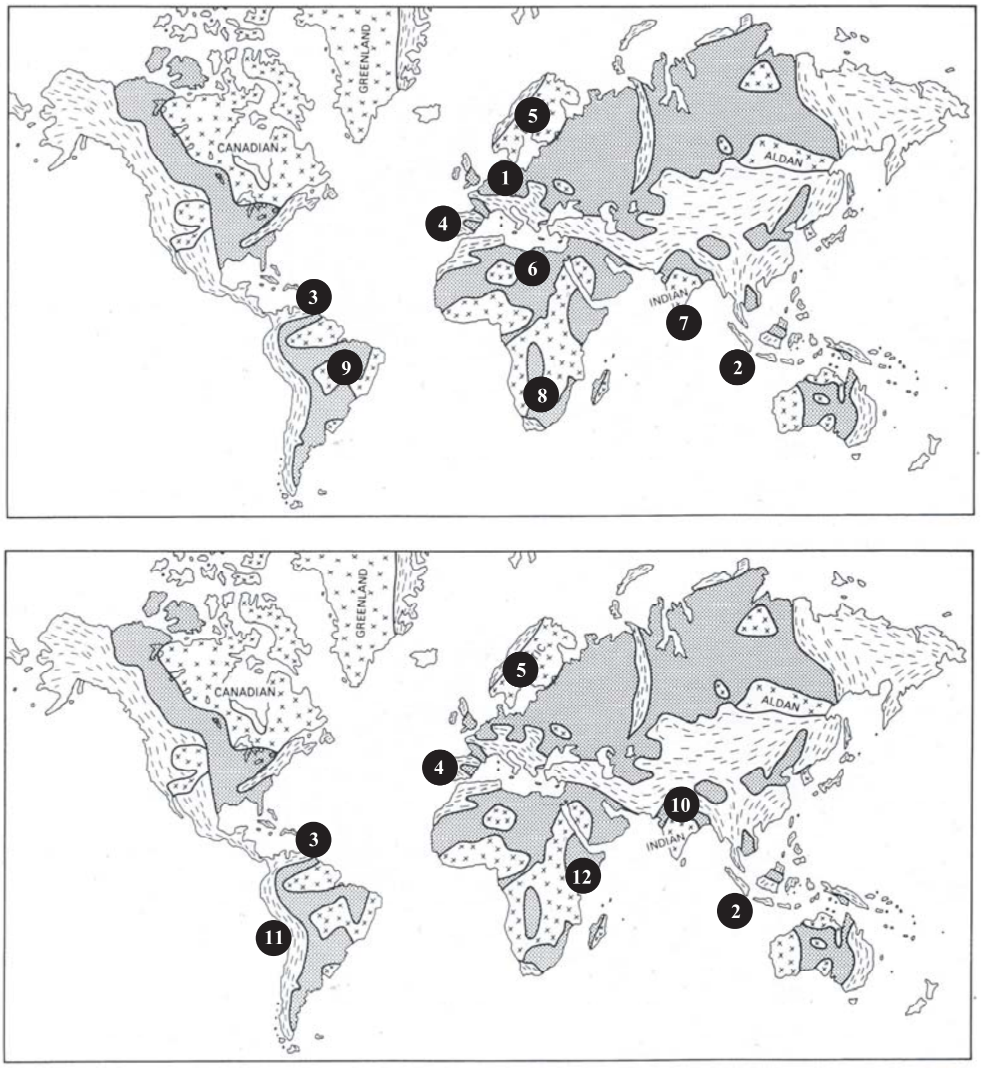

Fig. 3. Regional 'hotspots' of the Naturalis rock collections. (A) Situation before 2002, with highlights including The Netherlands (1) and its former overseas domains Indonesia (2) and Surinam + part of the Antilles (3); typical long-lasting projects areas in Spain (4) and Scandinavia (5), the Schürmann collection from North Africa (6), and classical gem provinces in Sri Lanka (7), southern Africa (8) and Brazil (9). (B) The new acquisitions from the University of Amsterdam (UvA) enhance the pre-existing regional strengths, with additional highlights from climbing expeditions in the Himalayas (10) and Andes (11), and major mapping projects in Tanzania (12).

The regional 'hotspots' of the Naturalis rock collections are shown in Fig. 3a. The main regions underline the history of geological research in the Netherlands, starting from the country itself and its former overseas domains, and the long-lasting project areas in Spain and Scandinavia, that became an increasing focus of attention after loss of the colonies. The Von Siebold collection is mainly of historical importance, but cannot be regarded as representative for the rich geological variety of Japan and neighbouring countries.

Collection highlights from the UvA include the Permian fossils of Timor, presently housed at the Geological Museum of Artis in Amsterdam; material from expeditions to the former Dutch East Indies; Caribbean collections (fossils & volcanics); collections related to *c*. 80 Ph.D. dissertations; and material from climbing expeditions to the Himalayas and Andes in the 1950s. It is clear that the new acquisitions from the University of Amsterdam (Fig. 3b), amounting to *c*. 49,000 rock samples, *c*. 16,000 fossil specimens and *c*. 100,000 thin sections, enhance the pre-existing regional strengths (Fig. 3a), with additional highlights from climbing expeditions and major mapping projects in Tanzania.

From acquisition to second life

Promoting a second life — Acquisition is merely one step in the process leading towards future use of rock collections (see, e.g., Shelton, 1991; McGinley, 1992). Additional action points include digital registration of all samples of the most important collections; digital photographing of key samples (e.g., meteorites); publishing a catalogue at sub-collection level, possibly on the homepage; advertizing the presence and contents of (inter)national academic heritage to the Earth science community and the community at large; and stimulating international funding for museum visits, e.g., via recent EU funded programmes such as SYNTHESYS and Transnational Access. We intend to post a short description of all rock collections on the Naturalis homepage (www.naturalis.nl) in 2005, because only increased visibility is likely to generate collection re-use.

Examples of a second life — The new acquisitions as well as older collections (see below) can be used in pilot studies carried out either before submitting research proposals or at an early stage of projects. Researchers will be invited to study theses, maps and thin sections; to reinvestigate and analyse old material, using more advanced techniques or new insights not available at the time it was collected; to build on existing collections and then to define what kind of additional specimens are still required for a specific research theme. This may be a more cost-efficient way of running projects than to start again from scratch, collecting samples in the field. To give some examples, fossil material from the Caribbean and crustal xenoliths from southern Spain are currently being studied by Naturalis staff members, in collaboration with foreign researchers and integrated into larger scale projects.

Old collections can also be re-used for teaching purposes, notably thin sections, mineral specimens and fossils. The thin section collections host a large variety of igneous and metamorphic phenomena from many tectonic settings and countries. A reference collection for such phenomena could be lent to universities for teaching purposes. Material from type localities and reference material (holotypes) must be identified and preferably be stored separately.

Modernizing old collections — The rock collection philosophy adopted also has a bearing on existing academic collections at Naturalis, most of which have been inherited from the Geology Department of Leiden University. These collections have generally been left intact, without any selection, and thus include poor quality student collections, excess excursion collections (many years to the same region), etc. They are not of a higher standard than the UvA collections and therefore ought to be treated the same way. De-selecting and de-accessioning parts of these collections is recommended as a forward looking strategy (see, e.g., Cannon-Brookes, 1992; Ainslie, 1999), aimed at providing space for possible future acquisitions, either from The Netherlands (e.g., University of Utrecht, oil companies?) or abroad.

Discussion — As mentioned by de Clercq (2004), the procedure adopted here to select and de-select academic collections, and to promote collection mobility, is expensive and probably only possible under special circumstances. A lot of money and energy can be saved when researchers themselves make a selection of the material they have collected, allocating the material to various levels of uniqueness and future research potential, and removing poor quality material before they leave a research institution. It is rather common practice that active researchers take the best material with them to the next assignment, leaving behind the poor quality material. Whether they can keep the best material or not is a matter of agreement between them and their former host institution. In the absence of proper collection managment, it may be the best option. Leaving behind the left-overs should not be promoted.

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