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Statement by

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Dr Ana Carneiro co-edited with Dr. Marianne Klemun a special issue titled *Seeing and Measuring, Constructing and Judging: Instruments in the History of the Earth Sciences* to be released at the end of April 2011. This is the second issue of *Centaurus* volume 53.

She co-authored with Dr. Klemun 'Instruments of Science – Instruments of Geology', published in this volume.

In this special issue the article written by Teresa Salomé Mota entitled 'A bursting landscape in the middle of Portugal: theories and experiments by Georges Zbyszewski' (18 pp.) will be published.

*Ida Stamhuis*

# Instruments of Science—Instruments of Geology. Introduction to Seeing and Measuring, Constructing and Judging: Instruments in the History of the Earth Sciences

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*Abstract.* This essay provides an overview of the main features of the literature produced in the history of science on scientific instruments, as well as of the articles published in this special issue of *Centaurus*. From almost neglect or of marginal interest to mainstream historians during many years, the 1970s mark a shift in the study of scientific instruments. But the growing interest in their multifarious roles developed especially from the late eighties onwards, culminating, in the early 21<sup>st</sup> century, with a wealth of studies addressing scientific instruments and the complex web of social, cultural, political and economic aspects associated with them. The history of geology has paid scant attention to this topic, chiefly because geologists themselves see field rather than laboratory work as the main distinctive feature of their science. It was precisely this fact that motivated the organization of this special issue of *Centaurus*, which aims at contributing to the topic by bringing together articles, focussing on the use of instruments in the earth sciences, in different local and temporal contexts.

*Keywords.* Communication, economy, experiment, instrument-makers, instruments, scientific

The telescope and microscope were probably two of the most widely respected and well-known instruments of the 17th century. From the point of view of the history of science, too, they were soon inseparably related to the beginning of modern science in the 17th century. But when Alexandre Koyré (1943) attributed a purely illustrative function to them, he greatly reduced their prominence. Koyré gave a portrayal of the major figure of this epoch, Galileo Galilei, in which as a Platonist, he first thought out his scientific facts and then used the instruments merely to communicate them.

The argument as to whether the head, the idea or the theory constituted the origin of knowledge was therefore for many years the centre of interest of the history of science, but today it is the hands, the materials, the media and the space that tell their own story.

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The history of these instruments was neglected for very many years in the history of science. It remained of marginal interest because the function of the instruments was reduced to the activity of measurement. At the same time it was understood as an unproblematic operation, a simple piece of translation.

A very full history of the aesthetic impact of instruments, the history of manufacturers and workshops, local traditions and distribution, together with modern collections, cannot alter the fact that for many years the epistemic significance of instruments went unrecognized.

Instruments have a communicative function. They link nature to elements of science and scientific cultures, and these processes have proved to be highly complex. In *Leviathan and the Air Pump* (Shapin and Schaffer, 1985) the authors described the use of instruments in a variety of settings, together with the rhetoric of presentation and modest witnessing as the technologies that enable scientific life. Recently the history of the manufacturers of instruments has also experienced an elevation in its status in respect of its subjects. Galison's *Image and Logic* (Galison, 1997) puts this group of professionals alongside the great theorists and experimental scientists.

Gerard Turner, who initiated in the 1970s the publication of his many studies on scientific instruments, became a reference in this field, especially for instruments and apparatuses used in astronomy, micrography, physics and chemistry. Among his contributions, in the book *Elizabethan Instrument Makers* (Turner, 2000) he presents instruments within a broader cultural context, that of Europe in the 16th century when a period of unprecedented vitality and innovation in science and trade began.

Alison Morrison-Low in her study *Making Scientific Instruments in the Industrial Revolution* (2007) puts the focus on the previously undervalued role of the instrument-maker's craft, in its heyday between 1750 and 1851, a period that covers both the Industrial Revolution and the development of the British Empire. A combination of historical approaches including economic, family, scientific and technological, thus demonstrate their potential value for history in general. It shows social heterogeneity both among the group of instrument-makers and among users. Competition to produce the best quality instruments led progressively to educational goals, and these are manifest in the production of instruments for use in schools. This implies a distinction between supply and demand.

Since Hacking's seminal *Representing and Intervening* (Hacking, 1983), philosophers of science have acknowledged instruments as being of central importance to the practice of science. What is still open is the significance they should be given in the acquisition, stabilization and dissemination of knowledge and evidence.

While Davis Baird (*Thing Knowledge*) (Baird, 2004), for example, argues that instruments contain knowledge of how to produce effects, Latour (1988) has argued that facts and artefacts are elaborated in the same way. The use of instruments in science is usually associated with the laboratory, a space regulated by specific norms of practice, which to a great extent are transversal to the various experimental sciences. In this

context, instruments became not only powerful tools of observation and/or measurement, but also symbols of the values shared throughout time by scientific communities working in 'labsapes' (Kohler, 2002), like accuracy, precision (Gooday, 1990) and objectivity (Daston and Galison, 2007).

The concept of 'experimental systems,' from the historian of biology Hans Jörg Rheinberger (1992), defines as an object of research the entire microcosm of the working scientist. It contains not only the experimental arrangements including the instruments, but also the disciplinary, institutional and social dispositions in the form of an 'amalgam' that is very difficult to separate. This approach may be viewed as a landmark for all subsequent research in all fields of science.

Whilst words, pictures and instruments are brought together in the collection *Transmitting Knowledge*, 2006, edited by Sachiko Kusukawa and Ian MacLean (Kusukawa and Maclean, 2006), in their collection, entitled *Instruments, Travel and Science* (2002), Bourguet, Licoppe and Sibum examine the interplay between travel and instruments. In this work the historical process which gave rise to an instrumental culture is analyzed, and various authors trace the circulation and appropriation around the world of instruments, skills, practices and values associated with them, as well as the tensions between the local and the global, from the 17th to the 20th century.

Among the authors dealing with more recent historical periods, Rabinow, Sibum and Schickore produced methodologically distinct accounts of the use of instruments in different disciplines, with a particular emphasis on biotechnology, physics and biomedicine.

Within a broader project on the anthropologization of the West, Paul Rabinow carried out an ethnographic study of polymerase chain reaction (PCR), a biotechnological invention, by focusing on the assembling and managing of scientific and technical capabilities, team work, legal questions and material resources (Rabinow, 1996). PCR is a technique in molecular biology and a routine component of every molecular biological laboratory which differs fundamentally from other techniques, such as cloning, in producing a single artificial copy of a biological unit. PCR is more radical as it instrumentalizes Nature by converting a natural process into an artificial machine which itself produces genetic material.

Also within the life sciences, but with a different orientation and scope, Schickore contributes a study on a paradigmatic instrument, the microscope. In the early 19th century, the microscope was greatly perfected, its use was expanded and it became essential to the development of cell theory and to the education of physicians. But by linking together scientific methodology with the history of the life sciences, medicine and of vision, Schickore shows that the history of this optical instrument is entwined with that of the eye (Schickore, 2007).

Schickore makes a distinction between two concepts: 'second-order practices' and 'second-order discourses.' She is using these to refer to those practices and discourses which do not relate to the object of investigation as such, but which are reflexively concerned with the methods used. Contemporaries used these to focus attention on the

limits of the instruments and the place of the observer. In this way Schickore embeds her analysis in the complex discourse landscape. Instruments as extensions of human senses are also one of the topics that Sibum reflects upon, but in the realm of physics. He argues that from the mid-18th to the early 20th century, the establishment of experimental physics as an academic discipline challenged the still-dominant epistemological divide between knowing and doing. Sibum argues that by the turn of the 20th century, experiment had become a powerful way of knowing in science. The technological character of experimentation was often seen as an extension of the human senses, opening up new realms of experience, which contributed to shaping different areas of theoretical physics (Sibum, 2004).

Philippe Despoix analyses, along the lines of cultural history, the discourses and forms of knowledge derived from Enlightenment exploration through the European voyages of circumnavigation, between 1770 and 1780 (Despoix, 2005). He emphasizes the simultaneously aesthetic and scientific forms of knowledge and focuses on the *dispositifs*, which correspond to a variety of apparatuses and machines, diagrams or networks. Concomitantly, a number of new characters and craftsmen emerge such as the clock-maker with his sea chronometers, the explorer like Cook or Bougainville, the natives and the European public.

Despite the wealth of studies on the use of instruments in other disciplines of the Earth sciences, traditionally, the history of geology has paid scant attention to this topic mainly because geologists themselves see field rather than laboratory work as the main distinctive feature of their science. As they have assumed that, in essence, geology is not experimental, with the exception of instruments like seismographs used in geophysics (Oldroyd, 1996), they have not placed the laboratory and the use of instruments at the core of their practice (Newcomb, 2009).

This special issue of *Centaurus* focuses on the use of instruments in the Earth sciences. It gathers together articles which aim at contributing to a reflection on the use of instruments and apparatuses with specific purposes and in distinct spatio-temporal contexts.

The tendency towards micro-history and everyday history that has dominated general history in recent decades can also be found in this volume transferred to the history of science, in that attention is directed to local scientific practices and cultures. The focus on the singular moments of great discoveries was extended in favour of the reconstruction of routines in both the field and the laboratory.

### *1. Instruments in the earth sciences*

The articles grouped in this issue cover a wide range of topics, spanning from the use of the simplest tool to contemporary sophisticated electronic devices; from measurement to experiment and simulation, in the field or in the laboratory.

The first article by Marianne Klemun, 'The Geologist's Hammer—"fossil" tool, equipment, instrument and/or badge?' traces the story of the multifarious meanings of the geologist's hammer and its almost magical appeal. It is not only the instruments that travel, as portrayed in the collection edited by Bourquet *et al.* (2002), but also changed meanings travel with them. The author argues that from the end of the 18th century onwards the hammer played a key role in fieldwork, which, in turn, became a constitutive element in the establishment of geology as a science. But Klemun also shows how in a local culture the hammer became an instrument of classification, between c.1780 and 1810; how its unchanged features grounds the reference to it being a 'fossil' tool, which is nevertheless required as an extension of the geologist's hand; finally, how the hammer became a fetish for many geologists, in the sense of building an identity for the profession, who organized collections of hammers from more or less famous owners, as well as a symbol of the profession as shown on emblems and badges of many geological societies and organizations.

Ezio Vaccari, with his article titled 'Travelling with instruments: Italian geologists in the field between the 18th and 19th centuries,' shows that there is no divide between the use of instruments and fieldwork, which generally involves a particular kind of travelling along the lines of Marie-Noëlle Bourquet *et al.* (2002). He establishes a connection between the use of instruments and different practices of geological travelling in Italy and focuses both on instruments designed for specific purposes, which became standard, and on others that were soon abandoned as being impractical. Depictions of these instruments used in fieldwork and in the laboratory were found by the author in manuscripts, but many found their way into printed books, articles and memoirs on geological excursions and expeditions. Vaccari argues that while measuring instruments such as those used in cartography, geodesy and geophysics have merited the attention of historians of geology, the field equipment used in palaeontology, mineralogy and mining has not awakened the same amount of interest among historians on the grounds that it is too basic. Vaccari focuses on a whole array of instruments used by travelling geologists or mineralogists in the 18th century, which included thermometers, barometers and hygrometers, as well as portable kits for chemical-mineralogical analysis, often encompassing hydrostatic scales, goniometers and small crucibles, together with hammers and walking sticks, which, as the author argues, contributed to the definition of a new style of mineralogical and later geological travelling, in late 18th-century Europe.

In their joint paper entitled 'Searching for modernization—Instruments in the development of earth sciences in Portugal (18th century),' Isabel Malaquias and Manuel Pinto focus on the close relationship in Portugal between mercantilism and the use of instruments in 18th-century earth sciences. Here a connection between politics and modernization is opened up, as had been discussed much more fully by Morrison-Low in her book (Morrison-Low, 2007). Between 1750 and 1777, the Marquis of Pombal, then prime minister, implemented economic policies based on the exploitation of mineral resources in mainland Portugal and in Brazil, then a Portuguese colony. The wealth of

the country was then heavily dependent on Brazilian gold and diamonds. Although they do not draw on Despoix's notion of *dispositifs*, Malaquias and Pinto adopt a broad notion of instrument, and single out a number of instruments whose production, circulation and use were associated with both economic and educational policies of mercantilist orientation. In this context, they not only focus on books, papers and other written material, but also on instruments, such as barometers and weighing balances, which were made, replicated and circulated in academia and among surveyors.

Thomas Brandstetter, with his innovative article entitled 'Time Machines: Model Experiments in Geology,' analyses the different uses of model experiments in 19th and early 20th century geology and claims that they not only served as 'models of,' that is imitations of certain real-world phenomena, but also as 'models for,' which means that they were used as research instruments. The author discusses experiments with models in the field of geology in the context of the functions of models for the mindscapes of geologists, as technologies of imagination. From this perspective, the significance of experiments goes far beyond the evaluation of theories; instead their role as media is emphasized, which aims at providing the geologists with a feeling for tectonic processes.

Their qualities had a representative character that was derived from empirical analysis of rock behaviour and from scaling principles borrowed from engineering. Despite their possible educational purposes, models and model experiments have been used chiefly to decide between competing explanations and theories, as they show how geological events might have happened, rather than reveal their cause. But the author argues that in some instances, specifically when combined with photography and film, models become time-machines, as they facilitate the visualization of the very action of geological time. In this sense, Brandstetter convincingly argues that they are really 'technologies of the imagination,' as they allow geologists to visualize processes that cannot be grasped by human perception. In fact, they render geological time visible.

The article by Teresa Salomé Mota entitled 'A bursting landscape in the middle of Portugal: theories and experiments by Georges Zbyszewski' also provides a case-study of the use of model experiments in geology. Following a discussion of recent literature on the status of models and experiments in geology, Mota tells the story of the Russian-born French geologist Georges Zbyszewski, while supervising geological work in central Portugal, in a region known as the typhonic valley, whose origin puzzled him. Zbyszewski, who prior to living and working in Portugal had been trained as a geologist in France, was familiar with experimental geology. While working for the Portuguese Geological Survey, he designed, around 1946, a series of experiments with analogue models, which he carried out, in order to be able to respond to the pressing interests of the mining industry, then being promoted by the dictatorial regime known as *Estado Novo*. Although serving to a great extent Zbyszewski's purpose, these experiments had no real consequence for the practice of Portuguese geology, and only 40 years later did

his pioneering work find followers, when in the 1980s a school of experimental geology emerged at the University of Lisbon.

Moving now to another continent, Sílvia Figueirôa, with her article 'Minerals Scrutinized: Alberto Betim Paes Leme (1883–1938) and the Application of Spectrography.' Here she focuses on pioneering work in the application of spectrography in mineral analysis as performed by the Brazilian mineralogist Alberto Betim Paes Leme, a former graduate of the *Ecole des Mines*, in Paris. The author set out to analyze contextually the use made by Betim of this technique, as well as to discuss his methods and results. Despite the Brazilian mineralogist's local prestige and connections abroad, and the fact that his contributions to spectrochemical analyses were mentioned by a number of foreign experts, Figueirôa argues that Leme's work merits further attention and that he should be ranked among the pioneers of spectroscopic analysis, as his contributions were in tune with a broader movement that sought precision in science through the intensive use of scientific instruments, in the sense of Gooday (1990) and Daston and Galison (2007).

Finally, Gregory Good, in his 'Measuring the Inaccessible Earth: Geomagnetism, In Situ Measurements, Remote Sensing, and Proxy Data,' draws attention to the fact that the usual complex questions posed by measurement are magnified and further complicated when the object of study is out of reach. The author divided his essay into three sections in which he addressed a particular set of problems posed by the use of instruments in the geosciences, when the phenomena which are being studied are inaccessible, notably Earth's magnetism and electricity. The first section focuses on the separation of signals when they are intertwined in a single measurement; the second concentrated on the mapping of the Earth's surface, specifically on the variables which are measurable on the planet's surface; the third concerned the exploration of the Earth's upper atmosphere and near-space, which in the past was inaccessible but is now inhabited by satellites bearing instruments and measuring devices, together with the Earth's interior, immediately beneath our feet. Good's aim is not contrasting laboratory sciences and field sciences, or physical sciences and earth sciences. His comparisons are not drawn along disciplinary lines and no temporal progression is implied; rather, contemporary and past scientific research are addressed from the vantage point of accessibility and control, factors which, as the author argues, are not usually taken into account by historians of the geosciences.

Far from giving a systematic overview, in general terms this volume provides a discussion of a broad spectrum of different approaches to the not unambiguous phenomenon of the 'instrument.' The implicit inclusion of transfer-research in the works of Mota and Figueirôa, in which science cultures are transferred from France to Portugal and Brazil, is a factor that also plays a role, in the same way as the varying significance of individual instruments over the years in the works of Vaccari and Klemun. Instruments and the practices associated with them are seen by the authors of this collection either as the expressions of the different material conditions of structural difference



within particular science cultures, or as the mediators of science between different cultures.

Specific questions typical of Earth sciences are also asked, together with those universal questions about the function of the model (in Mota and Brandstetter), and providing solutions in inaccessible spaces (Good). Even the question of mercantilism cannot be excluded from this perspective (Malaquias and Pinto).

In spite of the clear link to the Earth sciences, it is the intention of this special issue of *Centaurus* that the history of instruments can also provide a successful response to the general need to bridge disciplinary borders.

With the help of the analysis of instruments the perspective broadens from the history of a single discipline to general aspects. This volume is very close to Michel Foucault's observation that quantitative practices and instruments should be understood as 'technologies of power' (Foucault, 1977).

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Sadly, on 15 January 2011, Manuel Serrano Pinto, contributor to this special issue of *Centaurus*, passed away. He was professor of geology at the University of Aveiro, Portugal, from which he had retired, and served as President of INHIGEO-INTERNATIONAL COMMISSION ON THE HISTORY OF GEOLOGICAL SCIENCES, from 2000 to 2004. The editors wish to express their sorrow and pay their respects to his memory.

### *Special Announcement*

The articles in this volume were first presented at the INHIGEO Symposium *Seeing and measuring, constructing and judging: Instruments in the History of the Earth Sciences*, organized in the context of the XXIII International Congress of History of Science and Technology, which took place in Budapest, from 28 July to 2 August, 2009. The participation of Ana Carneiro in this Symposium was funded by the research project PTDC/HCT/65345/2006, *The Portuguese Geological Survey (1848–1970): History and Scientific Heritage*, Portuguese Foundation for Science and Technology, FCT-MCTES.

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