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Book review: *Planetary Geoscience*

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McSween Jr., H. Y., Moersch, J. E., Burr, D. M., Dunne, W. M., Emery, J. P., Kah, L. C., and McCanta, M. C.: Planetary Geoscience, Cambridge University Press, 350 pp., ISBN 9781107145382, GBP 49.99, 2019.

1 Introduction

As geology is the science aimed at understanding the origin and functioning of the Earth, planetology wants to comprehend all planets of the solar system and the universe. Geosciences form a complex edifice of physical and chemical disciplines, namely mineralogy, petrology, geochemistry, volcanology, sedimentology, geomorphology, tectonics and geophysics, all dependent on the acquisition of data. On Earth, the collection of geological data mostly occurs through fieldwork, rock sampling and in situ measurements. For all other planets, data acquisition relies on remote observation, spacecraft exploration and meteorite analysis. Hence, even if geology is a branch of planetology, the one dedicated to the Earth, the two fields are historically separated and planetary science has rather been taught as part of the astronomy curriculum. Based on a multidisciplinary course provided by the seven authors at the University of Tennessee, this volume is the first textbook providing an exhaustive background to planetary science.

2 Chapter review

Composed of 17 chapters, the book begins with a preface signed by the seven authors, presenting the book's aims and the choices that have been made to shape it. The idea is to unravel all the geologic processes affecting planets, moons and smaller bodies (asteroids, comets) by providing the readers with all the tools they need. These tools are geology advanced majors to which are added specific tools related to space exploration and extraterrestrial samples.

The first chapter makes an inventory of the geologic bodies in the solar system. Rather than taking the traditional approach of stepping outward from the Sun to the Kuiper belt, the authors want to unroll the historical thread of discoveries made thanks to space exploration. This chapter is nevertheless a list of every known object, with a very short description of each of them, providing only the main facts together with the information of the missions dedicated to their respective explorations. This chapter is not aimed at giving details on either the techniques used or the objects. The interest of this overview comes from its shortness, which allows the reader to quickly get a global picture of what is the solar system, what do we know about each object and what remains to be explored. It also provides a small table comparing the physical parameters of each planet (heliocentric distance, mass, etc.) which is useful and easy to be learned by heart.

Chapters 2 and 3 are "Toolkits for the Planetary Geoscientist". Chapter 2 gives all the physical and technical background of spectroscopy and imaging, as remote sensing is the main bias of data collection in planetary science, operated by instruments aboard orbiting spacecrafts or landed rovers. As a nonspecialist of these techniques but working with the processed data (mainly surface compositions) they provide as raw material, I find this section relevant and exhaustive. This chapter lists all kinds of spectral information that can be acquired by robots, as well as the applications and the limitations of each spectral region. For example, X-ray emissions are diagnostic of the elemental composition of a planetary surface; yet, these rays require, for most elements, high-energy sources to be emitted. This explains why Mercury, the planet closest to the Sun, and therefore the one the most irradiated by its light, is the best investigated by this method. The following chapter, number 3, is about geological mapping, terrain dating and stratigraphy, i.e. the steps beyond ac-

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quiring spectral data. This chapter invokes classical geology basics complemented with crater-related dating methods and ends up with an evocation of the analysis of extraterrestrial samples, hence making the transition to the next chapter.

Chapter 4 seems at first glance to be about meteorites, as it is entitled "Solar System Raw Materials", but is more a general introduction to cosmochemistry. Although the chapter gives a good overview, it might lack some information. It starts with the origin of the elements; stellar nucleosynthesis is detailed, but the section could have gone a bit deeper into some general knowledge about the big bang and the steps driving the formation of the modern universe. Next, the condensation sequence is discussed. I may notice this because this is my field, but I think the condensation sequence part should have been developed a little further. A figure showing phase proportions along condensation paths instead of element fractions would help beginners to understand that the condensation sequence explains well, at first glance, the modal composition of chondrites and bulk planets and the compositional gradation correlated to heliocentric distance. Even if the chapter contains a box called "a crash course in chondrite petrology and classification", a real section dedicated to meteorites is missing; a figure showing the classification of meteorites and an annotated photo of a chondrite would be a minimum. The choice to introduce the geochemical properties of the elements here, rather than in the chapter about planetary differentiation, is hard to understand. Indeed, volatility-related processes could be explained at the same time as the condensation sequence, while metal–sulfide–silicate partitioning is mostly related to magma ocean processes such as core formation.

Chapter 5 is about accretion. It opens with a theoretical description of the canonical accretion model, mixing astronomical observation of extrasolar accretion discs and numerical simulation models. It is followed by a timing of the accretion processes, based on meteorite radiometric dating, and the question of the age of the Earth is discussed. The following section is devoted to the chemical composition of the bulk planets and their building blocks. I would have preferred this section to appear in the cosmochemistry chapter; also, some classical references are missing (McDonough, Palme, Dreibus, Wänke, etc.). A third section gives an exhaustive description of asteroids and comets, as detritus of planetary accretion. Chapter 5 ends up with the Moon formation story and give clues about the grand tack model. This section should directly follow the first part of the chapter, as it is about dynamics in the disc.

Chapter 6 is about planetary heating and differentiation, i.e. the magma ocean stage. Although rather exhaustive, a scheme showing a planet undergoing differentiation, and how elements partition between the different reservoirs, would have been welcome. This chapter uses information carried by differentiated meteorites that should have been extensively described in chapter 4. Chapter 7 couples geophysics and experimental petrology to provide the unseen interior of the terrestrial planets, the giant planets and their icy moons. This chapter is comprehensive. As a specialist of Mercury, I should however mention that recent work shows that its core likely contains substantial amounts of Si (and not S as is written). Finally, chapter 8 uses the knowledge developed in the two previous chapters as a basis to approach planetary geodynamics, each planet having a unique regime shaping its surface. This chapter is particularly important as it links the surfaces of planets (and eventually their atmospheres) to the properties and the motions in their interiors. It contains geology background (isostasy principles, gravity, fluid mechanics, etc.) punctuated with examples (planets and moons).

Chapters 9 sums up the structural data collected on planetary surfaces to compare the tectonic regimes of rocky planets and icy moons. This important chapter starts with a physics background and lists all the different structures that are found in the solar system (lobate scarps of Mercury, bands on Europa, grabens on Mars, etc.) and discusses the mechanisms driving to stagnant- or active-lid bodies. Organized according to a similar structure, chapter 10 is about planetary igneous activity. It starts with an igneous petrology background and travels then through the solar system to present all the different magmatic and volcanic activities that constructed (or still construct) planetary crusts. Petrological information is inferred from the analysis of natural samples (achondrites, Apollo samples, etc.) and remote spectral data. Exotic igneous processes, such as fire fountains erupting in the lunar vacuum or cryovolcanism on icy bodies, are described. As an extension of chapter 10, chapter 11 talks about impact cratering as an important geologic process being an integral part of planetary (including Earth) evolution.

Chapter 12 addresses the fundamental issue of the origin and evolution of volatile elements in planets, from their accretion to their release in the atmosphere by degassing their interior. This chapter compares all the planets by giving cosmo- and geochemistry elements. The question of the distribution of water in the solar system is well developed; however the figure showing the hydrogen isotopic compositions could be more complete (one would like to see at least the protosolar nebula value as well as martian meteorites or the atmosphere of Venus which are discussed in the text).

Chapters 13 to 16, all about surface processes, are outside my field, so I can only describe their content and remark that they are well written and illustrated. Chapter 13 is about eolian processes; chapter 14 is about fluvial and lacustrine land forming; and chapter 15 is about weathering and sedimentology, including a section about space weathering and regolith processes as well. Chapter 16 is an introduction to astrobiology, discussing the availability of life chemical ingredients in the universe and the notion of a "habitable zone" for planets.

The authors finally propose, in the last chapter of their book, the case study of Mars as an integrated planetary geoscience exercise. Starting with a history of spatial missions dedicated to the red planet, data of all scales are shown, going from the analysis of martian meteorites to global maps constructed by combining various remote spectral information. As this science is particularly well developed on Mars, a detailed stratigraphic study of the Burns formation in Endurance Crater is proposed. Even if I regret that experimental petrology is not used to unravel the interior of the planet, this chapter reaches its goal and is a nice way of summarizing the teachings of the whole book.

3 Conclusion

Beyond filling a gap that has surely been detrimental to generations of students and teachers approaching planetology, this book is very well written and illustrated and gives historical elements as well as the recent advances in each field; it is all in all a remarkably condensed format reduced to the essentials. The organization of the book is however sometimes surprising, and chapters could have been grouped to clarify the plan. In addition, references for key figures or concepts are sometimes missing.