PREFACE

We initiated this volume with the conviction that a better union of geologic insights with astronomical ideas and data would provide the clearest prospect for increasing our understanding of exoplanets and their evolution. We realized that close communication is key. Geologists, for example, can help refine testable hypotheses that would usefully influence the astronomical targets and measurements being made by current and upcoming telescopes. The focus for this RiMG volume is on rocky exoplanets because the search for truly Earth-like planets is of special interest. Our goal is to motivate communication between the disciplines so as to make the best use possible of existing data and data yet to be collected by the James Webb and the Nancy Grace Roman Space Telescopes, since the astronomy community is gathering data on stars and exoplanets at an accelerating rate. Such data now include exoplanet size and mass (i.e., density) as well as their atmospheric compositions, which are collectively telltale of mineralogy and evolution. Much of what is published may still fall in the realm of educated speculation, but our conjectures are metamorphosing into testable hypotheses. Another intriguing turn in the Astro-Geology connection is how the telescope must sometimes be turned back towards Earth, as our speculation on the exoplanets necessarily contends with incomplete knowledge of the origin and evolution of Earth and its planetary neighbors. We hope to share expertise that will our understanding of exoplanets to develop in pace with data collection.

We begin with chapters on exoplanet host stars (Hinkel et al.), and the compositions of proto-planetary disks (Zhang et al.). The properties and composition of host stars have been crucial to examining the range of possible exoplanet compositions that might exist in our part of the Milky Way; the following chapter on protoplanetary disks gives further constraints on the compositions of the materials from which rocky planets ultimately precipitate. This begins a conversation about how and why planets can differ in composition from the stars they orbit. The next chapters also have important implications for exoplanet compositions as they cover the physics of planetary formation (Mordasini and Burn), where location and timing of planetary accretion can affect the final product, and meteorites formed in our Solar system (Jones), which provide the clearest record we have of the earliest of planetary accretion processes. The next two chapters are on so-called “polluted white dwarfs”—their compositions (Xu et al.) and the physics of how white dwarf atmospheres become polluted (Veras et al.). The “polluted” varieties of white dwarfs normally have their otherwise pure H or He atmospheres polluted by the ingress of rocky planetary materials and so these very special stars may give us our most accurate estimates of exoplanet bulk compositions.

Our next three chapters use Earth and terrestrial processes as analogs to understand exoplanet mineralogy (Putirka), bulk rock type and fluid compositions (Guimond et al.) and tectonic processes (Putirka). For a planet to be Earth-like an as yet unknown range of minerals and rock types are needed so as to either allow or facilitate plate tectonics. Exoplanet mineralogy and rock types may still be uncertain, but these chapters explore some avenues of speculation. The next chapter reviews the cycling of “life-essential volatile elements” or LEVE (Dasgupta et al.) for rocky object within the inner Solar system, and then uses such, again as analogs, to interpret various observations of exoplanets. This review of LEVE is

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followed by a chapter on planetary magnetic fields (Brain et al.), including how such fields are generated, and how variations in magnetic properties can influence planetary evolution.

Of special interest is whether any exoplanet might harbor life and our next three chapters approach the issue. We start with measurements of the compositions of exoplanetary atmospheres (Kempton et al.), and the possible biosignatures (Schwieterman and Leung) that such atmospheres might contain. These chapters are followed by an Earth-based perspective on biogeochemistry, especially focused on the early Earth, which at present provides our only testing ground for how life is initiated. We then end the volume with a summary of future directions in exoplanet studies (Foley) so as to maximize the rate at which this new scientific discipline might evolve and advance.

There is now a remarkably large amount of astronomical data (with even more on the way) that geochemists and petrologists can make much use of. But just as astronomers may benefit from geologic insights, geologists need our colleagues in astronomy to help interpret their data and their underlying implications to better understand its astronomical context. Our hopes for this volume will be fulfilled if readers initiate their own analyses of what at present may seem like novel or unusual data, and if new collaborations between academic departments and subfields are forged.

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