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Review Article

The Types of Natural Resources on Terrestrial Planets and Extraterrestrial Civilizations

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ABSTRACT

In addition to energy resources, natural resources such as metals, metalloids, non-metals, hydrocarbons, etc. are among the elements needed for the creation of a civilization. One of the important debates about intelligent life is to know how extraterrestrial civilizations provide the energy and natural resources needed for their development. Previous studies have not discussed much about the ways which intelligent civilizations can access their energy and natural resources. This study discussed the types of natural resources on terrestrial planets and the types of extraterrestrial civilizations that could use them. The results showed that the type of natural resources in terrestrial planets depends on the amount of liquid water, crust lithology, tectonics style, and the presence of microorganisms on the surface of these planets. Among all types of terrestrial planets, plate tectonics style silicate planets have the most complete natural resources. So these planets can be good targets for the natural resources supply of hominid and superhuman extraterrestrial civilizations. Other terrestrial planets such as carbon planets, coreless planets, iron planets, moons and icy dwarf planets, and even gaseous giant planets, although not be civilizable, but have large natural resources that can be used by superhuman civilizations.

Keywords: Kardashev scale; Terrestrial planets; Natural resources

ABBREVIATION

Li: Lithium, Be: Beryllium, Na: Sodium, Mg: Magnesium, Al: Aluminium, K: Potassium, Ca: Calcium, Sc: Scandium, Ti: Titanium, Y: Yttrium, Zr: Zirconium, Nb: Niobium, Tc: Technetium, La: Lanthanum, Cs: Cesium, Pm: Promethium, Tm: Thulium, Re: Rhenium, Hg: Mercury, Pb: Lead, Ra: Radium.

INTRODUCTION

In many previous studies have discussed the effect of energy resources in the creation and development of civilization. But the effect of natural resources, such as metals, metalloids, non-metals, hydrocarbons, etc., is not less than the effect of energy resources in the creation and development of civilization. For this reason, this research focuses on natural resources that exist in terrestrial planets that can be used by extraterrestrial civilizations. In 1964, Russian astronomer Nikolai Kardashev provided a scale for classifying extraterrestrial civilizations according to the amount of energy they could obtain. According to this scale, the extraterrestrial civilizations when reaching higher levels of civilization increases their need for energy resources [1]. But these civilizations to achieve the higher levels of civilization, in addition to energy resources, they need natural resources such as metals, non-metals, metalloids elements, hydrocarbons, etc. to the manufacturing of tools and machines. These resources are found abundantly in terrestrial planets, and natural resources very easier extracted from terrestrial planets than the other cosmic bodies, such as the stars. Of course, cosmic bodies such as the stars are lack of elements heavier than iron, instead, they are found abundantly in the terrestrial planets divided the terrestrial planets into four groups: silicate planets, iron planets, coreless, and carbon planets. This study examines the types of natural resources on terrestrial planets according to Naeye classification for use by all types of extraterrestrial civilizations based on the Kardashev scale. The research showed that each one of the terrestrial planets has their natural resources that depend on the amount of liquid water, crust lithology, tectonics style, and the presence of micro-organisms on the planet's surface. Natural resources in each one of these planets can be available for special types of extraterrestrial civilizations [2].

KARDASHEV SCALE

The Kardashev scale is a criterion for classifying extraterrestrial civilizations based on the amount of energy they can obtain. In this classification, the extraterrestrial civilizations are classified into six types of "zero, one, two, three, four and five" in order of their development and the amount of energy they can obtain. According

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to this classification, zero and one type civilizations depend on their parent planet for obtaining energy (and of course natural resources), and cannot move further away from their parent planet for obtaining more energy. But the higher civilizations than one type civilization can move away from their parent planet to obtain the energy, and use from the other cosmic bodies such as the stars to gain more energy [3]. In this study, for the sake of an easy use from the Kardashev scale, the zero and one type civilizations are named "hominid civilization", and civilizations higher than the one type civilization are named "superhuman civilizations".

EFFECTIVE FACTORS IN THE TYPE OF NATURAL RESOURCES ON TERRESTRIAL PLANETS

The type of planetary tectonics style

Stern identified the types of tectonics styles on terrestrial planets as two types of "plate tectonics" and "stagnant lid tectonics". He also divided the tectonics style of the stagnant lid tectonics into four different phases, which respectively increasing of the thickness and strength of crust, including "heat pipe", "drips and plume", "delamination and upwelling", and "terminal stagnant lid tectonics". Except to the Earth, which has a plate tectonics style, all of the planets and moons in the solar system have a stagnant lid tectonic style. But the type of stagnant lid tectonics style in each one of these planets is different. The type of tectonics style determines the crust lithology, and the type of crust lithology determines the type of elements in the planet's crust. For example, the Jupiter's Io has a heat pipe stagnant lid tectonics style, and its crust is made of basaltic, anorthosite, and ultramafic rocks [4,5]. Venus has a stagnant lid tectonics style of drips and plume, and its crust rocks include tholeiitic basalt, gabbro, and syenite. Mars has a stagnant lid tectonics style of delamination and upwelling (Stern, 2016), and its crust is mainly made of basalt. Earth's moon and Mercury have the terminal stagnant lid tectonics phase (Stern, 2016), and their crust is composed of gabbro, basalt, and anorthosite (Figure 1).Large asteroids, such as the Vesta asteroid, which have a tectonics style of stagnant lid tectonics (Stern, 2016), have a crust composed of mafic (basalt) and ultramafic rocks. In the stagnant lid tectonics style, the crust lithology is confined to mafic and ultramafic rocks, and other igneous, sedimentary, and metamorphic rocks are absent in this tectonics style. But in the tectonics style of plate tectonics, there are different types of igneous, sedimentary, and metamorphic rocks. For this reason, planets with plate tectonics style have natural resources much more complete than the planets with stagnant lid tectonic style. However, natural resources on planets with stagnant lid tectonics style, although may be large in volume, but have a very little diversity.

Crust lithology

Natural resources such as metals, non-metals, and metalloids are valuable elements needed to produce various technologies in an advanced civilization. These elements are extracted from the ore minerals. On Earth, each type of rock has its valuable elements.For example, granite rocks found on planets with plate tectonics style contain elements such as Li, Be, F, Sn, W, U, Th, Au, Mo, Cu, Zn, Ag, and Pb . Pegmatite rocks, which are predominantly granitic in composition, and are found in planets with plate tectonics style, contain elements including Li, Br, Nb, Ta, Y, Zr, Cs, U, Th, Sn, W and REE (Rare Earth Elements). Carbonatites are also rocks found in planets with plate tectonics style contain elements such as REE, Al, U, Fe, Nb, and Sn. But mafic and ultramafic rocks (basalt, peridotite, anorthosite, and gabbro) that found in both planets with plate tectonics style and planets with stagnant lid tectonics style containing elements such as Cr, Fe, Co, Ni, V, Ti and PGE (Platinum Group Elements). All of these elements are found on the Earth, with plate tectonics style and all types of igneous, sedimentary, and metamorphic rocks. But on planets such as Mars, Venus, Mercury, the Earth's moon and asteroids such as Vesta asteroids that have stagnant lid tectonics style and mafic and ultramafic crust, the major elements in their crust include Fe, Ti, Cr, Ni and PGE. The planets with plate tectonics style, in addition to igneous rocks, have metamorphic and sedimentary rocks. There are also special elements in these rocks. For example, rocks derived from regional metamorphism produce uranium, and in contact metamorphisms derived from injection of granitic plutons into carbonate rocks, produce elements such as Cu, Pb, Zn, W, Sn, and Mo. Sedimentary rocks also have various elements such as the types of iron [6].

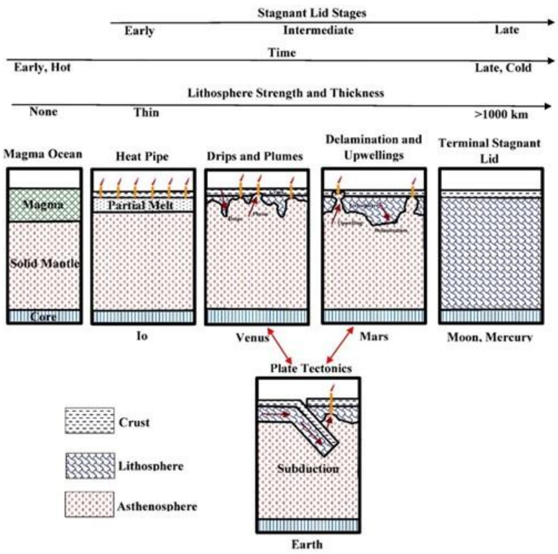

Figure 1: Types of tectonics style on terrestrial planets.

Liquid water

On Earth, water plays an important role in the production of life, plate tectonics, climate change and so on. But water also plays a role in the production of natural resources such as metals, non-metals, metalloids, and hydrocarbons. Deep heated waters (hydrothermal waters) contribute to the dissolution, transport, and the dispersion of metal ions and the formation of ore minerals and ore deposits [7]. These waters form large ore deposits of elements such as W, Sn, Au, Ag, U, Co, Sb, Hg, Zn, Pb, Cu, and Fe. Atmospheric water also plays an important role in the production of sedimentary ore deposits including U, Fe, Ni and Al. The Mars planet, which in the past had liquid water on its surface today has large ore deposits derived from hydrothermal waters including the ore deposits of Cu, Zn, Pb, Ag, As, Au, Te, Sb, Cd, and Se. In addition to the formation of metallic, nonmetallic and metalloid ore deposits, water also plays a role in the formation of hydrocarbons on the Earth. Phytoplanktons that are petroleum producer, live in aquatic environments. Source rock, reservoir rock and cap rock of hydrocarbon resources are mainly included sedimentary rocks that settle in aquatic environments. However, all hydrocarbons present in the crust or on the surface of the terrestrial planets are not with the organic origin, and liquid water has no role in their formation [8,9]. For example, the origin of hydrocarbons on the surface of Saturn's Titan, which mainly consists of methane and ethane, is a layer of methane hydrate with an approximate thickness of 100 km in the icy mantle of Titan, which remains stable under high internal pressure of Titan.

THE PRESENCE OF MICRO-ORGANISMS ON THE PLANET'S SURFACE

On Earth, phytoplanktons micro-organisms are a major component of petroleum. Advanced plants are the origin of coal, which is a primary energy resource. Bacteria are effective in the formation of biominerals such as some iron deposits. Bacteria also play a role in the stabilization of elements into sulfatic forms. Carbonates, phosphates, halides, sulfates, silica, iron oxides, manganese oxides, sulfides, and oxalates can be produced in microbial processes such as eukaryotic activity (bacteria and archaea).

THE TYPE OF TERRESTRIAL PLANETS AND THEIR NATURAL RESOURCES

Silicate planets

Earth, Mars, Venus, some moons and many asteroids in the solar system are of this type. Silicate planets with plate tectonics, diverse crust lithology, liquid water, and micro-organisms have the most complete metallic, non-metallic, metalloid, and hydrocarbon natural resources. In these planets, present felsic and intermediate igneous rocks such as granite, pegmatite, and carbonatite with elements such as Li, Br, Nb, Ta, Y, Zr, Cs, U, Th, Sn, W, REE, Al, Fe, Be, F , Au, Mo, Cu, Zn, Ag, and Pb. These planets also contain mafic and ultramafic igneous rocks such as gabbro, basalt, peridotite, and anorthosite that contain elements such as Cr, Fe, Co, Ni, V, PGE and Ti. In addition to igneous rocks, there are also sedimentary and metamorphic rocks on these planets that contain elements such as Fe, P, Mn, Al, Ni, U, Cu, Pb, Zn, W, Sn, Mo and Au. Such planets are capable of production and development of life on their surface, and with the creation of intelligent species on the surface of these planets, it is the present possibility of hominid civilizations formation. Thus the abundant and diverse natural resources on these planets can be available for both hominid and superhuman civilizations. But some other types of silicate planets have stagnant lid tectonics style, and their crust is made up only mafic and ultramafic igneous rocks. Such planets do not have liquid water, and there is no possibility of micro-organism's existence on the surface of them. Under these circumstances, it is no possibility of life and hominid civilization's existence [10-13]. The only natural resources available in these planets for superhuman civilizations are Cr, Fe, Ni, V, Co, Ti, and PGE

NATURAL RESOURCES IN GASEOUS GIANTS, ASTEROIDS, MOONS AND ICY DWARF PLANETS FOR THE USE OF EXTRATERRESTRIAL CIVILIZATIONS

Because of the lack of solid lithosphere, gaseous giants have no special natural resources such as metallic, non-metallic, metalloids elements and hydrocarbons. But these planets have a great resource of H and He-3 that can be an energy resource for using by superhuman civilizations[14-17].M type asteroids contain iron and nickel elements, and C type asteroids have water and PGE elements which can be available for superhuman civilizations. Some ice planets and moons have a water ice crust and liquid water asthenosphere. These terrestrial bodies are lacking plate tectonics and silicate crust. They, therefore, are lacking any metallic, non-metallic, metalloid elements and hydrocarbon on their surface. In these terrestrial bodies, only water can be used as a natural resource for the use of superhuman civilizations.

CONCLUSION

Research done indicates that terrestrial planets provide important natural resources to extraterrestrial civilizations that are absent in other cosmic bodies such as the stars or difficultly extracted from them. The type of natural resources on terrestrial planets depends on the type of tectonics style, the presence of liquid water, crust lithology, and the presence of micro-organisms on the planet's surface. Among all types of terrestrial planets, silicate planets with plate tectonics, in addition to producing life and creating hominid civilizations, also have the most diverse natural resources that can be available for both hominid and superhuman civilizations. Other types of terrestrial planets have stagnant lid tectonics, almost uniform crust lithology, and absence of liquid water on its surface, although in some cases may contain large volumes of natural resources, but these natural resources are not very diverse. In this type of terrestrial planets, the major natural resources that can be available for superhuman civilizations include Fe, Ni, Ti, V, Cr, Co, PGE, water, and hydrocarbons. This research is the first research that studied the natural resources in terrestrial planets, and the types of extraterrestrial civilizations that use these resources[18,19]. The findings of this study illustrate the role of natural resources in terrestrial bodies in the creation and development of extraterrestrial civilizations. Future researches in this field could include the usage of the types of natural resources in the process of creation and development of intelligent civilizations [20].

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