Academic Journal of Earth Sciences
ISSN: 2960-0162
DOI: 10.61784/ajes231206

A REVIEW OF GEOLOGICAL SURVEY RESEARCH ON WEATHERING CRUST COVERAGE AREAS AT HOME AND ABROAD

John Oliver
Large-Scale Scientific Information Systems, Jacobs University, Bremen, Germany.

Abstract: By collecting, translating, and studying a large number of domestic and foreign literature on weathering crust research, this article reviewed the current status of weathering crust research and elaborated on the role of red soil in southern China. Progress in causes, eras, environment and climate. In the form of cases, from theory and practice 2. An overview of the geological surveys of weathering crust coverage areas at home and abroad, focusing on successful cases in geology, geophysics, geochemistry, soil, remote sensing, and drilling geological surveys of special geological areas of weathering crust abroad. For example, in order to better serve the weathering crust of special landform areas in my country 1:50,000 geological mapping pilot work.
Keywords: Weathering crust; Southern Chinese red soil; Special landform area; Geophysical and geochemical exploration technology; Geological survey

1. Introduction

The geological survey in special areas aims to focus on major national needs and provide society with basic geological survey results that meet multi-objective needs. In the laterite-type weathering crust coverage area in southern China, information such as thickness, composition, structure, neotectonic movement, and underlying faults, caves, and bedrock features are key to serving the needs of economic construction. However, these contents are not available in traditional geology. It is not reflected in the figure that the weathering crust has been simplified and the information is insufficient to meet the needs of national economic construction. Therefore, it is necessary to strengthen the special landform area - the strong weathering crust in the south 1:5 Thousands of geological survey and research work. During the pilot mapping work of strong weathering crust in the southern coastal zone of China, a large number of domestic and foreign documents were collected and translated. The study concluded that there are few articles specifically reviewing the geological survey of weathering crust. .

2. CURRENT STATUS OF WEATHERING CRUST RESEARCH

The study of weathering crust is an old topic. For weathering and The earliest understanding of weathering zones can be dating back to 19 Century, Rodgers et al [1] and Belt [2] conducted a preliminary study on weathering. In recent years, the Papers and monographs on the study of weathering crust, especially ancient weathering crust, are in The quantity and quality are constantly increasing, mainly focusing on the weathering crust formation environment, age and causes. In terms of weathering rate research, Huang Laiming et al. [3] reviewed soil weathering rate measurement methods and their impact Progress in factor research; In terms of weathering landform research, Ollier [4] made a detailed discussion on weathering, weathering crust and a large number of small-scale landforms related to weathering, and basically summarized 20 century 80 Progress in various aspects of age weathering crust research; ring formed by weathering In terms of environmental research, Huang Zhenyu et al. [5] reviewed the current status and prospects of research on the impact of hydrochemical environment on rock properties; In terms of research on weathering mechanisms, Cui Zhijiu et al [6] reviewed 20 century 90 Regarding the overall research on planation issues before the mid-1990s, Li Sha et al. [7] reviewed the progress of biological weathering research, Zhu Xianfang et al. [8] reviewed the progress of chemical weathering research, and Li Fuchun et al. [9] reviewed the progress of primary silicate minerals. Regarding the research progress of weathering products, Liu Zaihua [10] reviewed the latest progress and prospects of research on rock weathering carbon sinks; In terms of comprehensive research on weathering crust, Li Dewen et al. [11] reviewed the current status and prospects of weathering crust research.

3. PROGRESS IN GEOLOGICAL SURVEYS OF WEATHERING CRUST COVERAGE AREAS AT HOME AND ABROAD

3.1 Research on Red Soil in Southern China and Geological Survey of Weathering Crust Coverage Areas

3.1.1 Research progress on red soil in southern China

Characteristics, development pattern and environmental significance of the red weathering crust in southern China is in 20th Century 90 s achieved Many advances, in terms of methods, are also dominated by soil science methods in the past. Shift to predominantly geochemical methods. Research on southern red soil can generally be divided into 3 stages: 20 century 30 era to 60 The period of research on the causes of the age; 20 century 70 era to 90 age age layer academic research period; 2000 Environmental changes and Paleolithic inscriptions chemical research period [12]. Sui Shuzhen et

al. [13] studied magnetic stratigraphy, chronostratigraphy, biostratigraphy, climate stratigraphy, isotope stratigraphy and cycle stratigraphy. 6 From this perspective, the main research status of China's red soil strata is summarized; Xu Zemin et al. [14] reviewed the formation of laterite overlying carbonate rocks in southern China. Mechanism research progress; Chen Xiuling et al. [15] studied the origin and chronology of red soil. By studying laterite and paleoenvironmental evolution, the Quaternary period in southern China The progress of red soil research is discussed and summarized in detail, and the current red soil research progress is proposed. Problems existing in soil research and future research priorities.

Regarding the material sources and genetic types of red soil in southern China, there are different types such as alluvial, diluvial, aeolian and foothill accumulation weathering. Same view. Some scholars believe that while affirming the water formation theory, they should not rule out the causes of glacial, biological and gravel weathering in local areas and their relationship with neotectonic movements [16]. It is generally believed that the formation of laterite-type weathering crust in southern China is the product of chemical weathering under the East Asian summer monsoon and tropical - subtropical warm and humid climate environments. Yuan Baoyin et al. [12] divided the red weathering crust into red soil weathering crust, red weathering crust, Red loam weathering crust and brick laterite weathering crust 3 kind; Zhu Zhaoyu et al [17] The red weathering crust is divided into bedrock weathering crust and loose sedimentary weathering crust; Li Fengquan et al. [18] divided the reticulated laterite into homogeneous and heterogeneous reticulated laterite.

Many scholars have begun to explore the extraction of environmental information contained in southern red soil, trying to establish a comparative relationship with the environmental change cycle of the loess - palaeosoil sequence. Liu Caicai et al. [19] systematically summarized the progress in geochronological research on laterite magnetic stratigraphy in southern China in recent years; Huang Zhenguo et al. [20] believe that the red weathering crust in southern China has been formed from the Paleogene to the present, and that the current weathering crust is the inheritance of ancient weathering crust; Liu Dongsheng et al. [21] believe that the Early Pleistocene was the development period of red soil, and the Middle Pleistocene was the most developed period of red soil, forming reticulated red soil; Xi Chengfan [22] It is believed that the red weathering crust rich in iron and aluminum oxides in South China is a thermal Products produced under high temperature and high humidity conditions in the subtropical zone, mainly formed in the Quaternary; Zhu Zhaoyu et al. [17] pointed out that during the Quaternary period in southern China, the development time of several variegated clays and reticulated red soils was related to the early Pleistocene. 1.8 ~ 1.6 Ma BP Marine Quaternary bottom boundary climate transition event, 0.9 ~ 0.7 Ma The climate cycle transition event of BP's " Mid-Pleistocene Revolution ", 0.5～0.1 Ma BP The climate suitable period and 0.07～0.01 Ma BP Geological and climatic events such as the last glacial period and the deglaciation period were roughly simultaneous. Research on geological disasters in the laterite environment of southern my country There are: Li Wanneng et al. [23] reviewed the causes of collapse in red soil hilly areas in the south. Research progress on the mechanism; Zhu Zhaoyu et al. [17] pointed out that there are With 3 Environmental problems of the Great Red Soil, as well as soil degradation and pollution of the Red Soil A series of soil comprehensive environmental disasters such as pollution, soil erosion and collapse.

3.1.2 Progress in geological survey of domestic weathering crust coverage areas

Special area geological mapping project since 2014 Taken since the start of the year A series of progresses have been made. Here we only focus on the Chinese Academy of Geological Sciences. " Special " published by Yu Jinsong et al. of the Institute of Geophysical and Geochemical Exploration Research results of "Application of Geophysical and Geochemical Exploration Technology for Mapping of Special Geological and Landform Areas " [24].

The Luoding area of Guangdong Province is a warm and humid landscape in South China, and the petrophysics Weathering is weak, chemical weathering is strong, element leaching is obvious, and weathering products contain It is difficult to find primary mineral fragments and rock fragments. Granite is widely distributed in the area A rock-like mass, which has been strongly weathered to form a huge red weathering crust, giving The task of filling out the map presented difficulties. Yu Jinsong et al. [24] studied Guangdong Luo Ding et al. 4 When jointly measuring strong weathering and mapping, point out the area currently obtained The distribution laws of geophysics and geochemistry are the result of complex geological processes. Objective reflection, using computers to process massive regional geophysics, geology geochemical data, extract rich geological information, and analyze regional geology Quality investigation work has important reference significance. petrogeochemistry The identification method is through major, trace, rare earth elements and isotopes etc., and reversely infer macrogeological information from the microscopic level The method can be used to solve problems such as petrogenesis, age, provenance, rock More detailed geological mapping such as stone types, mineral species and microfacies question.

In studying Inner Mongolia Fuxing City, etc. 4 During the joint amplitude measurement, it is pointed out that the hidden When detecting voltaic geological bodies, " gravity and magnetism " + " radon - mercury joint measurement " are used The joint exploration technology can effectively avoid gravity and magnetic ambiguity and radon - Mercury gas measurement is susceptible to environmental interference, which is to improve detection accuracy and increase Mature, economical and fast technical method with strong accuracy. In addition, in In terms of detecting active faults, radon - mercury joint measurement has become a An important technical method used by departments to monitor active structures.

3.2 Progress in geological surveys of weathering crust coverage areas abroad

3.2.1 Geochemical mapping of weathering crust

3.2.1.1 Multi-element geochemical data mapping of weathering crust

Central AustraliaPadbury, Bryah, Ye rrida this 3 indivual The area of the Proterozoic basin was nearly 2 000 km 2, 90% covered by weathering crust. Davy [25] conducted a special geochemical study on it and believed that in the Yerrida Basin, the weathering crust from mafic rocks is richer than the nearby weathering crust covering the sedimentary rocks. CaO, Ga, Sc and V, available at the same time MgO,Cr,Cu and Ni Distinguish between different types of mafic units. in Padbury The basin weathering crust is richer in iron, MnO, and P 2 O 5,As,Ba,F,Pb and Th. in weathering crust K 2 O.Ba and Sr The change in content is related to the change of the underlying bedrock from granite to sedimentary rock. Most river sediments and sheet-like alluvial deposits retain the chemical composition of the underlying bedrock. Therefore, weathering crust geochemical mapping helps determine the distribution of underlying bedrock and its mineralization potential (Figure 1).

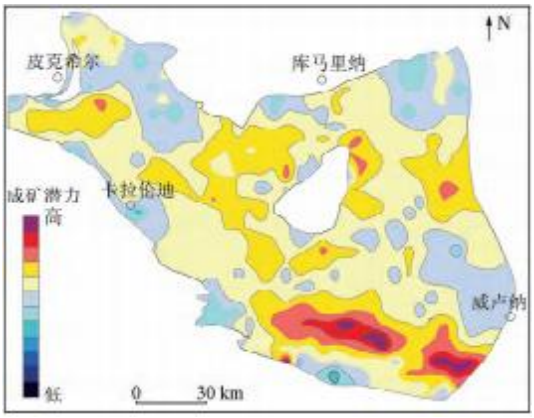

Fig. 1 Cu, Pb, Zn, As, Sb, Fe 2 O 3 + MnO terraforming Evaluation of mineralization potential after standardization of chemical elements [25]

3.2.1.2 Geological mapping of weathering crust radon gas

Since the on-site measurement of radon gas is greatly affected by seasonality, in order to carry out radon soil geological mapping, it is necessary to develop an in-situ method. 1 a any time within A method that can carry out field on-site radon gas measurements and radon gas potential mapping. Law. british geological survey Talbot[L. Are you waiting for [26] ? same of radon A large number of soil and gas samples were collected from the surface of potential bedrock areas. For each geological unit, samples covered by ice deposits and Samples were not covered by ice, and soil and soil gas samples were collected at the same depth (60 ~100 cm). Using on-site soil radon measurement, actual Laboratory radon emission analysis and field uranium gamma spectroscopy analysis 3 Zhongfang method, numerous comparative studies were conducted to evaluate on-site radon measurements effectiveness and timeliness. 3 The comparison results of the two methods show that the new On-site soil radon gas measurement can provide the most effective geochemical markers, providing a reliable basis for all-weather radon soil geological mapping in the field. It also provides technical means for new tectonic research.

3.2.1.3 Weathering crust Sr Isotope geological mapping

To study the origin and transport of chemical elements on the Earth's land surface and decentralized systems, Asahara etc [27] by Aichi Prefecture in central Japan is For example, with the help of Sr isotope ratios, geochemical mapping and physical Source analysis. In terms of distinguishing the sources of surface sediment materials, Sr isotope Ratio is a very useful tracer, especially where bedrock exposures are low area, as it has not suffered significant weathering and removal use. 87 reflecting river sediments Rb / 86 Sr – 87 Sr / 86 Sr Variety The map clearly reveals the differences in bedrock.

Most of the bedrock in the Japanese archipelago is covered by vegetation, soil and residential areas. This study collected 1 219 river sediment samples, conducted indoors Sr Isotope analysis. Sr Regional variations in isotope ratios show: In western and southeastern Japan, Sr The isotope ratio is higher, Sedimentary and metamorphic rocks are widely distributed in this area; In central Japan, Sr The isotope ratio is low and granite is widely distributed in this area. Research shows that use Sr Isotopes are very useful for geochemical mapping, revealing It shows the distribution of unexposed bedrock and the transportation of surface sediments. 2.2.2 Geophysical survey of weathering crust

Traditional geological mapping faces great challenges in deeply cut mountainous areas, areas with poor bedrock exposure, deeply weathered and widely distributed areas, areas covered by dense vegetation, and areas that are difficult to access. In such special geological locations It is particularly important to carry out geological mapping and geophysical survey in the geological area. 2.2.2.1 Aeronautical electromagnetic method

González - lvarez et al. [28] applied aviation in Neil residential area. The airborne electromagnetic method effectively detects the lateral and vertical changes of the weathering crust : ① The change in weathering crust thickness is 2 ~65 m; ②The transported sediments and siliceous conglomerate units covering the eluvial layer are widely distributed and the thickness for 5 ~45 m, and have low conductivity, these silicoconglomerate units are The upward change is larger, from completely cemented to permeable; ③Detect ancient The presence of channel networks and structural characteristics of caprock sedimentation. Its team is in On this basis, a three-dimensional structural model of the weathering crust was

established to provide The geological survey played a demonstration role. Currently, many geologists believe that Therefore, the airborne electromagnetic method combined with and constrained by the geological background is the most promising method to reveal the structure of weathering crust.

3.2.2.2 Aeronautical gamma spectroscopy measurement method

Airborne gamma spectroscopy measurements can better reflect rock characteristics, but Against the wind change shell thing quality and That point cloth special levy opposite reflect compare Difference. de Figueiredo Iza et al. [29] concluded that during the weathering process, due to the Reorganization of ball chemistry, redistribution of radioactive elements, weathering crust and Weathered material has a high eTh value, low K value and low— middle eU value . However only based on t / K.eU / K The ratio is insufficient To determine the weathering crust, it must be done with the shuttle radar topographic mapping (shuttle radar topography mission, SRTM) values and geology Features are combined using Boolean and fuzzy mathematical methods to give different Judgment based on different weights. Experiments show that fuzzy mathematics method comparison The degree is higher. This method has been used to adjust the red soil weathering crust of the Brazilian Amazon. It has been widely used in checking.

3.2.2.3 Resistivity chromatography X Radiography

Ritz et al [30] used resistivity chromatography X -ray photography technology, research The study covers eastern Senegal Wind tens of meters thick above 2 types of substrates Shell resistivity characteristics. Its two-dimensional resistivity profile reveals granite The heterogeneity of weathering crust above the basement explains a large amount of weathering crust information. Information, that is, the near-surface layer of weathering crust composed of unsaturated laterite material Soil has a high resistivity, and a clay layer containing a small amount of water in the middle has Lower resistivity, granite basement has extremely high resistivity, forming A typical sandwich structure. resistivity chromatography X -ray photography technology The use of methods mainly depends on physical, chemical, hydrogeological parameters The difference in resistivity of weathering crust determined by the number. Not only can weathering be identified Lateral inhomogeneities of the shell can also identify changes in vertical lithology, but must be combined with Comparative verification of the lithological surfaces revealed by mountain engineering, and the lithological surfaces at different depths Different electrode distances should be used for weathering crust to measure the apparent resistivity of weathering crust at different depths. Research results show that resistivity chromatography X -ray photography The measurement results are basically consistent with the field outcrops, and it is a fast and economical A feasible method for mapping granite weathering crust in tropical areas.

3.2.2.4 Hyperspectral remote sensing geological mapping

The weathering process involves changes in mineral composition and structure. The content and structure of feldspar in fresh rocks are key parameters that determine strong weathering. Hyperspectral images can reflect the lithology and mineralogy during the formation of landforms and landscapes. changes in species and geomorphological and climatic parameters. Riaza et al [31] by Spectral curves of weathered rocks measured using spectrometers in the field and laboratory lines, and then process the spectral curves, and finally obtain spectral characteristics that can identify lithological changes, which are highly consistent with the geological verification conducted in the field and have good results. Research shows that hyperspectral imagery can help determine weathering zone fronts and granite with different degrees of weathering, help assess the extent to which denudation controls terrain, and help produce soil loss and protection maps. In addition, UAV hyperspectral remote sensing technology has also been successfully applied In the field of geological mapping of special landform areas.

3.2.3 Comprehensive geological survey of weathering crust

Uganda's geological exploration is low and weathered Strongly, Bahiru et al. [32] used Landsat TM, SRTM and potential databases (put radiometry and magnetism), to Uganda Buhweju Strongly weathered areas Comprehensive geological mapping was performed. Apply image processing and enhancement techniques to improve the quality of various aerospace data, such as radioactive composite images fusion and enhancement processing. Combined with multispectral remote sensing data and Landsat digital elevation model, lithology can be better identified. Similar radioactive measurement signals can determine and delineate various basement rocks unit. Airborne electromagnetic data reveal valuable lithology in study area The relationship with magnetic anomalies has been determined NNE Xianghe NNW toward the structure system and delineated the prospecting target area. Research points out that aviation electromagnetics and geology Layers, minerals, geochemistry, drilling, geomorphic landscapes in the background The organic combination will become a powerful tool in revealing the structure of weathering crust, which is important for prospecting in areas where weathering crust dominates. Big impact.

3.2.4 Soil geological mapping

In the past, geological maps rarely expressed the content of soil. However, this information is very important for understanding the first Quaternary geology and landform formation processes are very useful. Costantini et al. [33] took the Quaternary paleosol of Montanara in central Italy as an example (The Pleistocene soil parameters in this area are derived from conventional soil surveys, special surveys and analytical data studying pedogenesis), developed a method for generating detailed geological maps of the Quaternary cover using soil survey and paleosol research results (Fig. 2). By defining "pedostratigraphic level" (i.e. soil strata are defined as soil Characteristic combination layers of soil origin, and these soils are formed from materials with a certain degree of weathering and comparable age to standard soils), based on the thickness of the weathering crust and the age of the oldest soil layer in the soil stratigraphic map, the Quaternary geological map is generated, and based on the comparative age, thickness and landscape of the soil, the Quaternary is divided in detail to enrich the content of the map.

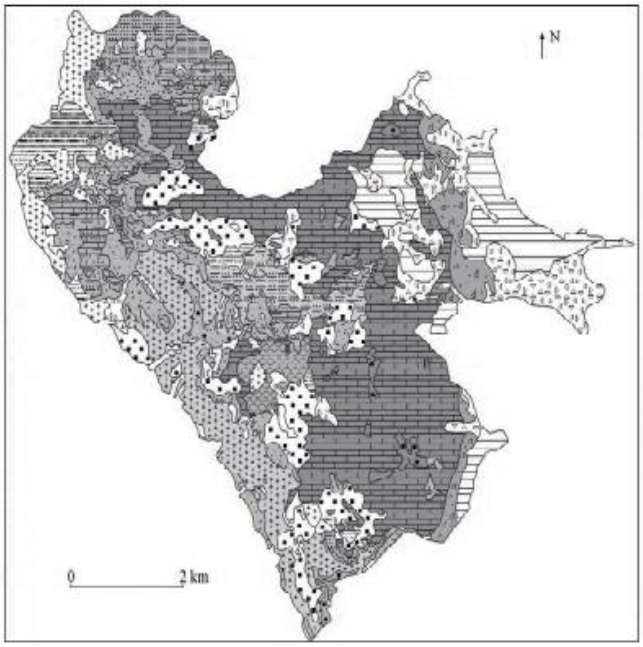

Figure 2 Geological map of Montanara's Quaternary overburden [33]

3.2.5 Random forest lithology prediction method

The random forest method is a supervised classification method that requires each Representative lithologies are trained for prediction or thematic mapping. Geochemical data and gamma spectroscopy data are lithology prediction The best measured parameters. Harris et al. [34] used random forest lithology prediction Measurement method, take 2 A training program using interpolated primary and secondary geochemical data and airborne electromagnetic and airborne gamma spectroscopy measurements for northern Canada Hearne Most of the lithology in the Archean and Paleoproterozoic tectonic domains were predicted, meaningful lithology prediction maps were produced, and field verification was conducted, achieving good results. Research has shown that this method is helpful for field geological mapping in areas where predicted geology does not match traditional geology and where exposure is poor.

4. CONCLUSION AND OUTLOOK

"special" features that are different from traditional mapping areas, and appropriate technical methods or a combination of multiple technologies need to be used to achieve mapping goals. There are currently many relatively mature geophysical and geochemical exploration techniques and methods. For example, geophysical exploration has derived many branch technologies within the traditional " gravity, magnetic, electrical, and seismic " method system. Geochemical exploration has derived from regional geochemistry. Exploration has developed into unconventional geochemical exploration, and there are many technologies in this field. In the process of transformation of geological survey methods, geophysical and geochemical exploration technology is undoubtedly one of the indispensable driving forces for innovation. However, it should also be noted that for emerging special geological and geomorphological area mapping work, the selection and matching of different technical methods also requires the testing and improvement of technical applications. For geological mapping, geophysical and geochemical exploration technology is also an indirect method, which still has certain constraints, limitations or multiple solutions, and its inference results also need to undergo falsification and confirmation tests [24].

The investigation and research of weathering crust is a comprehensive topic, an exploratory and practical work, which heralds the birth of new theories. It is not only necessary to conduct detailed research in depth vertically, but also to collaborate horizontally across disciplines to strengthen geology and soil science, geomorphology, climatology, biophysical chemistry, geophysics, geochemistry, mineral deposits, hydrology, and environmental geology. Comprehensive research in science and engineering geology. According to the thinking of system theory, dynamic weathering events and static influencing factors should be further studied, a weathering system formation model suitable for strong weathering crust in southern China should be established, and a multi-cycle high-resolution weathering crust of red soil - climate - planation in southern China should be constructed. Sequence of layers. At the same time, we update the mapping concept, innovate the geological survey and research work on weathering crust in special landform areas, strengthen the sustainable development of weathering crust research, and actively solve problems related to wind and weathering. Resource and environmental issues related to shelling.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Rodgers W B, Rogers R E. On the decomposition and partial solu- tion of minerals and rocks by pure water and water charged with carbonic acid. Am J Sci, 1848, 5 : 401－405.
[2] Belt T. The Naturalist in Nicaragua. Chicago: University ofChicago Press, 1874: 326.
[3] Huang Laiming, Shao Mingan, Jia Xiaoxu, etc. Research progress on soil weathering rate measurement methods and its influencing factors. Advances in Earth Sciences, 2016, 31 (10): 1021-1031.
[4]Ollier CD. Deep weathering, groundwater and climate. Geogr Ann: Ser A, Phys Geogr, 1988, 70(4): 285-290.
[5] Huang Zhenyu, Wei Changfu, Zhong Xiaobin, etc. Current status and prospects of research on the influence of hydrochemical environment on rock properties. Journal of Guilin University of Technology, 2013, 33 (2): 290 - 296.
[6] Cui Zhijiu, Li Dewen, Wu Yongqiu, etc. About the planation surface. Science Bulletin, 1998, 43(17): 1794-1805.
[7] Li Sha, Li Fuchun, Cheng Liangjuan. Research progress on biological weathering. Minerals and Geology, 2006, 20(6): 577-582.
[8] Zhu Xianfang, Li Xiangyu, Luan Ling. Progress in chemical weathering research. Journal of Capital Normal University: Natural Science Edition, 2010, 31(3): 40-46.
[9] Li Fuchun, Li Sha, Yang Yongzhao, etc. Research progress on weathering products of primary silicate minerals - taking mica and feldspar as examples. Journal of Rock and Mineralogy, 2006, 25(5): 440-448.
[10] Liu Zaihua. The latest progress and prospects of rock weathering carbon sink research. Science Bulletin, 2012, 57(2/3): 95-102.
[11] Li Dewen, Cui Zhijiu, Liu Gengnian. Current status and prospects of weathering crust research. Acta Earth Sinica, 2002, 23(3): 283-288.
[12] Yuan Baoyin, Xia Zhengkai, Li Baosheng, etc. Issues on chronostratigraphy and stratigraphic division of red soil in southern China. Quaternary Research, 2008, 28(1): 1-13.
[13] Sui Shuzhen, Yao Xiaofeng. Quaternary red soil strata in southern China. Quaternary Research, 2000, 20(2): 182-185.
[14] Xu Zemin, Huang Runqiu, Tang Zhengguang, etc. Progress in research on the formation mechanism of laterite overlying carbonate rocks in southern China. Earth and Environment, 2005, 33(4): 29-36.
[15] Chen Xiuling, Li Zhizhong, Jin Jianhui, et al. Research progress on Quaternary red soil in southern China. Journal of Fujian Normal University: Natural Science Edition, 2009, 25 (5): 118 -
124.
[16] Hu Xuefeng, Cheng Tianfan, Wu Heting. Is it possible that there are multiple cycles of "sedimentation-pedogenesis" in the reticulated red soil in the south? . Science Bulletin, 2003, 48(9): 969 -975.
[17] Zhu Zhaoyu, Wu Yi, Qiu Shifan, etc. The occurrence layers and age issues of the Quaternary reticulate red soil along the coast of South China. Advances in Earth Sciences, 2010, 25 (4): 391 -399.
[18] Li Fengquan, Ye Wei, Zhu Lidong, etc. Types and reticulation of Quaternary reticulated laterite. Journal of Sedimentation, 2010, 28(2): 346-355.
[19] Liu Caicai, Deng Chenglong. Progress in geochronological research on laterite magnetic stratigraphy in southern China. Frontiers of Earth Science, 2011, 18(4): 158-170.
[20] Huang Zhenguo, Zhang Weiqiang. Coupling of climatic and tectonic phases in the laterite period of China. Acta Geographica Sinica, 2000, 55(2): 200-208.
[21] Liu Dongsheng, Shi Yafeng, Wang Rujian, etc. Comparison table of China's Quaternary strata marked by climate change. Quaternary Research, 2000, 20(2): 108-128.
[22] Xi Chengfan. On the red weathering crust in South China. Quaternary Research, 1991, 11(1): 1-8.
[23] Li Wanneng, Jin Pingwei, Li Lanbin, et al. Research progress on the causes of collapse in red soil hilly areas in southern China. Subtropical Soil and Water Conservation, 2014, 26(3): 30-33, 43.
[24] Yu Jinsong, Jinglei, Wang Qiaolin, et al. Application of mapping and geochemical exploration technology in special geological and landform areas. Journal of Geomechanics, 2016, 22(4): 893-906.
[25] Davy R, Pirajno F, Sanders AJ, et al. Regolith geochemical mapping as an adjunct to geological mapping and exploration; examples from three contiguous Proterozoic basins in Western Australia. J Geochem Explor, 1999, 66(1/2): 37-53.
[26] Talbot ŁDK, Appleton JD, Ball TK, et al. A comparison of field and laboratory analytical methods for radon site investigation[J. J Geochem Explor, 1998, 65(1): 79-90.
[27] Asahara Y, Ishiguro H, Tanaka T, et al. Application of Sr isotopes to geochemical mapping and provenance analysis: The case of Ai- chi Prefecture, central Japan. Appl Geochem, 2006, 21 (3) :419－436.
[28] González－lvarez I, Ley －Cooper A Y, Salama W. A geological assessment of airborne electromagnetics for mineral exploration through deeply weathered profiles in the southeast Yilgarn Craton- ic margin, Western Australia. Ore Geol Rev, 2016, 73 : 522 -539.
[29] de Figueiredo Iza E R H, Horbe A M C, Silva A M. Boolean and fuzzy methods for identifying lateritic regoliths in the Brazilian Amazon using gamma-ray spectrometric and topographic data Geoderma, 2016, 269 : 27－38.
[30] Ritz M, Parisot J C, Diouf S, et al. Electrical imaging of lateritic weathering mantles over granitic and metamorphic basement of eastern Senegal, West Africa. J Appl Geophys, 1999, 41 (4) :335－344.

[31] Riaza A, Strobl P, Beisl U, et al. Spectral mapping of rock weathe- ring degrees on granite using hyperspectral DAIS 7915 spectrome- ter data. Int J Appl Earth Obs Geoinf, 2001, 3 (4) : 345 -354.
[32] Bahiru E A, Woldai T. Integrated geological mapping approach and gold mineralization in Buhweju area, Uganda. Ore GeolRev, 2016, 72 : 777－793.
[33] Costantini E A C, Napoli R, D 'Egidio G. Adding information about soils and paleosols to geological maps, through the applica- tion of the"pedostratigraphic level"concept. Quat Int, 2007, 175(1) : 125 －139.
[34] Harris J R, Grunsky E C. Predictive lithological mapping of Cana- da's North using random forest classification applied to geophysi- cal and geochemical data. Comput Geosci, 2015, 80 : 9－25.