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前 言

随着科学技术和生产的迅速发展，人们对矿产资源的需求日益增长．近 25 ～ 30 年世界矿产消耗量相当于在此之前全部人类消耗量的总和．为了适应矿产资源消耗量迅速增长的需要，就必须不断地预测评价各类矿产资源的可能数量、质量及其空间位置．自 70 年代以来，世界各国对矿产资源的统计预测评价问题十分重视，许多著名的数学地质学家都从事矿产资源统计预测和评价方面的研究．近年来，在世界范围内，矿产资源统计预测无论是理论、方法还是实际应用均发展很快，并取得了明显的成就，为各国矿产资源的科学规划、决策和合理勘探、开发、利用提供了宝贵的定量依据．因此，矿产资源统计预测已成为数学地质学中最受重视，最为活跃的一个重要分支．

矿产资源统计预测所研究的问题很多，涉及面很广，包括各个矿种各种类型矿床的小、中、大比例尺的统计预测．其中既有理论问题(如各种模型、规律、准则等)，也有方法问题(如变量的构置、变换、取值与筛选；各种情况下的预测方法；各种统计方法或其它数学方法在矿产资源预测中的应用；统计预测的成果形式问题等)，还有各种实际应用的案例和经验以及计算机程序系统、矿产资源预测评价专家系统的建立等问题．近年来，以上诸问题的研究都取得了显著成效，积累了较丰富的经验．为交流这些成果和经验、讨论共同关心的问题、加强国际学术联系与合作、进一步促进矿产资源统计预测学科的深入发展，由中国地质大学(武汉)、国际数学地质协会(IAMG)、国际地科联地质数据存储、自动处理与检索委员会(COGEODATA)、中国地质学会数学地质专业委员会等共同发起，并由加拿大地质调查所F．P．Agterberg 教授和G．F．Bonham－Carter 教授协助组织，经过努力筹备，顺利召开了这次“矿产资源统计预测国际学术讨论会”．

会议得到了国际、国内数学地质界的专家、学者们的热烈响应和广泛支持，特别还得到了国家自然科学基金会、“王宽诚教育基金会”的大力资助，在此我们深表谢意．大会共收到论文摘要 104 篇．该摘要汇编分四个专题编印：统计预测理论；统计预测方法；统计预测应用；其它．为了便于广大中外读者阅读，每篇摘要都用中、英文对照．该论文摘要汇编是由中国地质大学数学地质遥感地质研究所王仁铎、魏民、张光前、金友渔、胡光道审核整理，徐秉涛、郭凡民、葛亚非、王仁铎、张光前进行英语审校，《地球科学》编辑部王亨君、杨勇、李平编辑出版的，在此一并致谢．

矿产资源统计预测国际
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1990 .3 .29

PREFACE

With the development of science and technology , and production , the demand for the mineral resources has been increassing day by day . The consumption of the mineral resources in the whole world for the past 25 – 30 years is approximately equivalent to the total consumption by human beings before that time . In line with the demand for the increasing consumption of the mineral resources , the potential quantities , qualities and locations in space of all kinds of mineral resources must be statistically predicted and evaluated without any interruption . Since 1970's much attention has been paid to statistical predicting and evaluation of the mineral resources in all parts of the world . Many famous geomathematician have been involved in the researches into the statistical predicting and evaluation of the mineral resources . For the recent years much progress has already been made in the field of statistical predicting of the world – wide mineral resources in terms of its theory , method or application . The significant achievements thus made provide us with precious quantitative basis for the scientific planning and decision , reasonable exploration , development , and application of the mineral resources in different countries . Therefore , the statistical predicting of the mineral resources has become an important branch and also a focus on mathematical geology .

There are many problems to be solved and many fields to be covered with regard to the statistical predicting of the mineral resources , such as the statistical predicting of the small , medium and large scales for the different kinds of minerals and mineral deposits . The researches cover some theoretical problems (such as different kinds of models , law and principles), methodological problems (such as the construction , transformation , valuation and selection of the variables ; the predicting methods in different situations ; the application of different statistical methods or other mathematical methods to the predicting of mineral resources ; and the formats of the results approached in the statistical predicting), varieties of cases and experiences in terms of practical application , the construction of computer programming system and expert system used for the predicting and evaluation of mineral resources , etc . For the past several years , significant results have been obtained and richer experience has been accumulated in terms of the researches into the above – mentioned problems .The present " International Workshop on Statistical Prediction of Mineral Resources " is smoothly held in China University of Geosciences , Wuhan , for the purpose of exchanges of these results and experiences , the discussion of the problems concerned by all parties , the enhancement of international academic communication and cooperation , and the promotion of the development in statistical prediction of mineral resources . The workshop is sponsored by China University of Geosciences (Wuhan), IAMG , COGEODATA, and the Commission of Mathematical Geology under China Geological Association , and assisted by Professor F.P. Agterberg and Professor F. Bonham – Carter in

Canadian Geological Survey .

The workshop has gained warm responses , broad support from experts and scholars in mathematical geology at home and abroad , and to be particular , acquired substantial financial aids from China National Commission on Natural Sciences Fundation and "K . C . Wong Education Fundation, Hong Kong " , to which we express deep gratitude here . The workshop has received 104 abstracts of the articles . These abstracts are compiled under four headings : statistical predicting theory , statistical predicting method , statistical predicting application , and others . For the convenience of the readers at home and abroad , every abstract is printed in both Chinese and English languages . The abstract book is compiled and examined by Wang Renduo , Wei Min , Zhang Guangqian , Jin Youyu and Hu Guangdao in the Research Institute of Mathematical Geology and Remote Sensing Geology , China University of Geosciences (Wuhan) ; and its English version is examined and proofread by Xu Bingtao , Guo Fanmin , Ge Yafei , Wang Renduo and Zhang Guangqian . The editors of this abstract book are Wang Hengjun , Yang Yong and Li Ping of the editorial department of "EARTH SCIENCE " , to whom we express our thanks .

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International Workshop on Statistical
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SPATIAL RELATIONSHIPS OF MULTIVARIATE DATA

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A significant advantage of multivariate methods is that they reduce the number of variables required to describe the relationships between the variables and the relationships between the samples. However, these methods do not account for the relationships of the samples over geographical space. This can be achieved by the use of the method of spatial factor analysis.

Spatial factor analysis (SFA) is a multivariate method that extracts factor scores of variables with common spatial characteristics. This is achieved by deriving estimates of auto-and crosscorrelations of the variables. The method can be applied over a range of neighbourhoods to extract factors that are spatially significant for specific ranges. A number of autocorrelation models can be applied to the data which can yield different estimates of the spatial association.

A one-point spatial factor analysis model derives factors by the formation of transition matrix comparing auto-/crosscorrelations at lag '0' with a specified lag '*d*'. This can be expressed as:

$$[U]=[R_0]^{-1}[R_d]$$

The matrix U can be decomposed into its spectral components which represent the different spatial factors. Large positive (>>1)or negative (>> -1) eigenvalues can occur as a result of approximate linear relationships between the variables which can be the result of a lack of precision in estimation of the functions. Anisotropy can also cause the method to fail. The success of the technique depends on the amount of associated noise and the size of the neighbourhood relative to the spatial range of the variables considered.

A quantitative assessment of the goodness of fit can be applied to the results using squared multiple correlation coefficients. Thus, each spatial factor can be tested as to its contribution to the overall spatial structure of the data.

This technique is being extended to include two reference points. The corresponding spatial factors can be derived from the following relationship:

$$\begin{bmatrix} U_1 \\ U_2 \end{bmatrix} = \begin{bmatrix} R_0 R_{d1} \\ R_{d1} R_0 \end{bmatrix}^{-1} \begin{bmatrix} R_{d1} \\ R_{d2} \end{bmatrix}$$

The factors derived from this relationship assess simultaneously, the spatial continuity of the variables over two lag distances R_{d1} and R_{d2}.

The technique has significant applications in studies where several variables have different spatial ranges or zones of influence . SFA has been applied to multiple unconditional simulations , geochemical datasets ,and remotely sensed data . The advantages of SFA are illustrated when it is compared with standard principal components analysis .

多元数据的空间关系

E. C. Grunsky　　F. P. Agterberg

多元方法的一个显著优点就是可减少描述变量之间及样品之间所要求的变量个数. 但是, 这些方法并未考虑在地理空间上各样品之间的关系. 而这可以通过应用空间因子分析来达到.

空间因子分析(SFA)是一种多元方法,它用常见空间特征来提取变量的因子得分. 它是通过对变量的自相关和互相关估计量的推导而实现的. 该法可用来在邻域内提取那些在一定变程内有空间意义的因子. 有多种自相关模型能被用于那些可以产出具有空间联系的不同估计量的数据上.

单点空间因子分析模型通过比较'0'滞后与'd'滞后的自相关 / 互相关,形成转移矩阵的办法来得到所需的因子. 这可表示如下:

$$[U]=[R_0]^{-1}[R_d]$$

矩阵 U 可分解成代表不同空间因子的谱分量. 如果对函数的估计不很精确,则变量之间会有近似线性的关系,并产生绝对值很大(>> 1)的特征值. 各向异性也可能使此方法失效. 该方法的成功取决于有关噪声的数量和邻域的规模(是相对于所考虑变量的空间变程来说的).

用复相关系数的平方可对结果的拟合优度进行定量地评价. 这样,就能够检测出每个空间因子对整个数据空间结构的贡献大小.

该方法正被推广到两个参考点的情况. 对应的空间因子可从下列关系式中得到:

$$\begin{bmatrix} U_1 \\ U_2 \end{bmatrix} = \begin{bmatrix} R_0\, R_{d1} \\ R_{d1}\, R_0 \end{bmatrix}^{-1} \begin{bmatrix} R_{d1} \\ R_{d2} \end{bmatrix}$$

从这个关系式得到的诸因子,可同时评价在两个滞后距离 R_{d1} 和 R_{d2} 上的变量的空间连续性. 该方法可有效地用来研究那些具有不同空间变程或影响带的多个变量. SFA 已经被应用于多重非条件模拟、地球化学数据集以及遥感数据上. 当与标准主成分分析相比较时,SFA 的优点就充分显示出来了.

(王仁铎译)