(12) 特許協力条約に基づいて公開された国際出願

(19) 世界知的所有権機関
国際事務局

(43) 国際公開日
2015 年 2 月 19 日(19.02.2015)

WIPO | PCT

(10) 国際公開番号
WO 2015/022806 A1

(51) 国際特許分類:
G01V 9/00 (2006.01)

(21) 国際出願番号: PCT/JP2014/065556

(22) 国際出願日: 2014 年 6 月 12 日(12.06.2014)

(25) 国際出願の言語: 日本語

(26) 国際公開の言語: 日本語

(30) 優先権データ:
特願 2013-168564 2013 年 8 月 14 日(14.08.2013) JP

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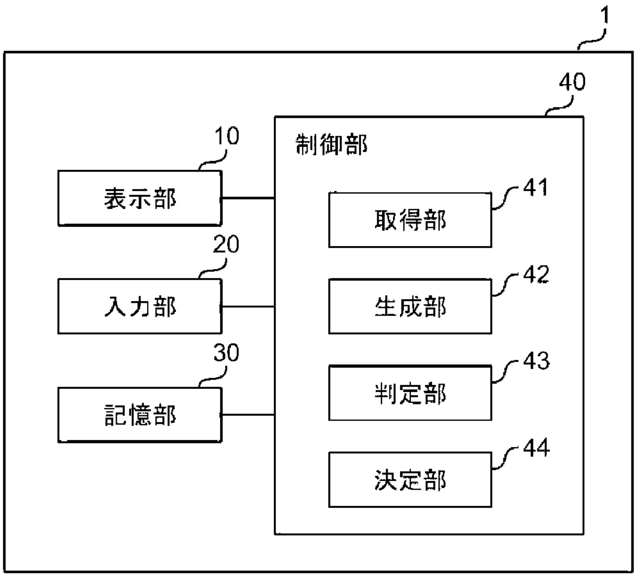
(81) 指定国 (表示のない限り、全ての種類の国内保護が可能): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) 指定国 (表示のない限り、全ての種類の広域保護が可能): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), ユーラシア (AM, AZ, BY, KG, KZ, RU, TJ, TM), ヨーロッパ (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI

[続葉有]

(54) **Title**: CRUST DATA ANALYSIS METHOD, CRUST DATA ANALYSIS PROGRAM, AND CRUST DATA ANALYSIS DEVICE

(54) 発明の名称 : 地殻データ解析方法、地殻データ解析プログラム及び地殻データ解析装置



10 Display unit
20 Input unit
30 Memory unit
40 Control unit
41 Acquisition unit
42 Generation unit
43 Determination unit
44 Setting unit

(57) **Abstract**: A crust data analysis device (1) is provided with: an acquisition unit (41) for acquiring a plurality of data items indicating the crustal abundance of a prescribed element or compound at a plurality of locations; a generation unit (42) for using differing first thresholds to delete, from the plurality of data items, data for which the crustal abundance is greater than or equal to the first threshold corresponding to the data item and generating a plurality of data items for which deletion has been completed; a determination unit (43) for determining whether the data composing the data items for which deletion has been completed conforms to a normal distribution having the average crustal abundance of the prescribed element or compound within an area larger than the area including the plurality of positions as the mean thereof; and a setting unit (44) for setting a geochemical anomaly threshold to the maximum crustal abundance value in the data item for which deletion has been completed having the smallest amount of data from among the plurality of data items for which deletion has been completed that have been determined to not conform to the normal distribution.

(57) 要約:

[続葉有]

WO 2015/022806 A1

(BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

添付公開書類:
— 国際調査報告（条約第 21 条(3)）

地殻データ解析装置１は、複数の位置における所定の元素又は化合物の地殻存在度を示す複数のデータを取得する取得部４１と、それぞれ異なる第１の閾値を用いて、複数のデータから、当該複数のデータの地殻存在度が第１の閾値以上のデータを削除して、複数の削除済データを生成する生成部４２と、削除済データを構成する複数のデータが、複数の位置を含むエリアよりも広いエリアにおける所定元素又は化合物の平均地殻存在度を平均値とする正規分布に従うか否かを判定する判定部４３と、正規分布に従わないと判定された複数の削除済データのうち、最もデータ数が少ない削除済データにおける最大の地殻存在度の値を地化学異常の閾値に決定する決定部４４とを備える。

TITLE: CRUST DATA ANALYSIS METHOD, CRUST DATA ANALYSIS PROGRAM, AND CRUST DATA ANALYSIS DEVICE

TECHNICAL FIELD

[0001] This invention relates to a crust data analysis method, a crust data analysis program, and a crust data analysis device used for geochemical exploration.

BACKGROUND OF THE INVENTION

[0002] In data analysis of geochemical exploration, it is known that the amount of contained material in a plurality of samples gathered from a crust has a normal distribution in a common logarithm. FIG. 9 shows an example of a frequency distribution of a background value corresponding to a common content ratio of contained elements and an anomalous value indicating the presence of a mineral occurrence in each rock in the plurality of samples gathered from the crust. In FIG. 9, the horizontal axis represents the amount of contained material in a common logarithm and the vertical axis represents a number of samples corresponding to each of the amount of contained material. FIG. 9 shows a frequency distribution FD1 of the background value and a frequency distribution FD2 of the anomalous value. The frequency distribution FD1 of the background value and the frequency distribution FD2 of the anomalous value tend to have a normal distribution independently.

[0003] Conventionally, a threshold value of elements contained in the plurality of samples is set with respect to a frequency distribution of the elements contained in the plurality of samples in order to separate the plurality of samples gathered from the crust into a background population and an anomalous population.

[0004] For example, a technique is disclosed for reading the threshold value between the background population and the anomalous population according to a bending point of a straight line in the cumulative frequency distribution by focusing on the fact that the plurality of pieces of data belonging to a population that has a normal distribution in a common logarithm shows the straight line in the cumulative frequency distribution among data indicating the amount of contained material of each of the plurality of samples (for example, see Non-Patent Document 1).

[0005] FIG. 10 is a cumulative frequency distribution map of the analytical values of each element in each of the plurality of samples. In FIG. 10, the horizontal line represents the amount of content of each element and the vertical line represents a normal distribution probability. In FIG. 10, for example, it can be recognized that the straight line indicating the cumulative frequency of molybdenum (Mo) bends at about 2 ppm and at about 8 ppm. Hence, it can be recognized that the line segment of about 2 ppm or less is formed by the background population, the line segment from about 2 ppm to about 8 ppm is formed by the background population and the anomalous population, and the line segment of about 8 ppm or more is formed by the anomalous population. Accordingly, a threshold value between the population corresponding to the background value and the population corresponding to the anomalous value of Mo can be set between about 2 ppm and about 8 ppm. Further, as another technique for determining the threshold value, a technique that determines a threshold value with a multiple of a value obtained by adding the standard deviation to the average value of the common logarithm is disclosed (for example, see Non-Patent Document 2).

PRIOR ART

NON-PATENT DOCUMENTS

[0006] Non-Patent Document 1: Lepeltier, C. (1969), A simplified statistical treatment of geochemical data by graphical representation. Econ. Geol., 64, 538-550.

Non-Patent Document 2: the Ministry of International Trade and Industry (1986) the wide area geological structure survey for fiscal 1986, the Structural Analysis Integral Analysis Report, p. 641.

SUMMARY OF INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0007] However, even if the threshold value between the background population and the anomalous population is desired to be determined on the basis of the amount of contained material of the plurality of samples, it is often the case that the bending point is not clearly shown as shown in FIG. 9. Accordingly, even if the technique disclosed in Non-Patent Document 1 is used, there is a case where it is difficult to set the threshold value.

[0008] Further, even if the technique disclosed in Non-Patent Document 2 is used, there is a case where a true average value and a true standard deviation cannot be obtained by giving a half value of a detection limit value to a piece of data below the detection limit of the geochemical analysis. Furthermore, there is a problem that the threshold value cannot be appropriately set to the population that apparently does not have a normal distribution even if the technique disclosed in Non-Patent Document 2 is applied.

[0009] Accordingly, it is desired to appropriately set the threshold value of geochemical anomalies for the population that does not have a normal distribution and the plurality of pieces of data containing data below the detection limit of the geochemical analysis.

[0010] The present invention is to provide a crust data analysis method, a crust data analysis program, and a crust data analysis device capable of appropriately setting the threshold value of geochemical anomalies.

MEANS FOR SOLVING THE PROBLEMS

[0011] A crust data analysis method according to the present invention comprises acquiring a plurality of pieces of data indicating crustal abundances of predetermined elements or compounds at a plurality of positions, generating a plurality of pieces of non-deleted data by deleting a portion of data from the plurality of pieces of data, deciding whether or not a plurality of pieces of data constituting the non-deleted data has a normal distribution with respect to each piece of the plurality of pieces of non-deleted data, and determining a threshold value of geochemical anomalies on the basis of a result of the decision.

[0012] Further, in the crust data analysis method according to the present invention, the generating the plurality of pieces of non-deleted data may generate a plurality of pieces of non-deleted data by deleting data in which a crustal abundances of the plurality of pieces of data is equal to or greater than the first threshold value from the plurality of pieces of data by using each different first threshold value, the deciding may decide whether or not a plurality of pieces of data constituting the non-deleted data has a normal distribution in which an average value is the average crustal abundance of the predetermined elements or compounds in an area that is wider than an area including the plurality of positions, and the determining the threshold value may determine a value within a predetermined range from the largest crustal abundance value in the non-deleted data with the smallest number of pieces of data among the plurality of pieces of non-deleted data that was decided not to have a normal distribution to be the threshold value of geochemical anomalies.

[0013] Furthermore, in the crust data analysis method according to the present invention, the generating the plurality of pieces of non-deleted data may generate the plurality of pieces of non-deleted data by deleting data in which the crustal abundance of the plurality of pieces of data is equal to or greater than the first threshold value by using each different first threshold value and by deleting data that is equal to or less than a second threshold value by using the second threshold value that is lower than the first threshold value from the plurality of pieces of data.

[0014] Moreover, in the crust data analysis method according to the present invention, the second threshold value is a detection limitation of the crustal abundance, and the generating the plurality of pieces of non-deleted data may generate the non-deleted data by deleting data that is equal to or greater than the first threshold value after deleting the data that is equal to or less than the second threshold value.

[0015] Further, in the crust data analysis method according to the present invention, the generating the plurality of pieces of non-deleted data may generate the plurality of pieces of non-deleted data by sequentially reducing the first threshold value, and the deciding may make the decision after a piece of the non-deleted data is generated.

[0016] In the crust data analysis method according to the present invention, the generating the plurality of pieces of non-deleted data may determine the first threshold value on the basis of a binary search and generates the non-deleted data on the basis of the determined first threshold value.

[0017] A crust data analysis program according to the present invention that causes a computer to operate as an acquiring section that acquires a plurality of pieces of data indicating crustal abundances of predetermined elements or compounds at a plurality of positions, a generating section that generates a plurality of pieces of non-deleted data by deleting a portion of data from the plurality of pieces of data, a deciding section that decides whether or not a plurality of pieces of data constituting the non-deleted data has a normal distribution with respect to each piece of the plurality of pieces of non-deleted data, and a determining section that determines a threshold value of geochemical anomalies on the basis of a result of the decision.

[0018] A crust data analysis device according to the present invention comprises an acquiring section that acquires a plurality of pieces of data indicating crustal abundances of predetermined elements or compounds at a plurality of positions, a generating section that generates a plurality of pieces of non-deleted data by deleting a portion of data from the plurality of pieces of data, a deciding section that decides whether or not a plurality of pieces of data constituting the non-deleted data has a normal distribution with respect to each piece of the plurality of pieces of non-deleted data, and a determining section that determines a threshold value of geochemical anomalies on the basis of a result of the decision.

EFFECT OF THE INVENTION

[0019] According to the present invention, the threshold value of geochemical anomalies can be appropriately set.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

FIG. 1 shows a functional configuration of a crust data analysis device according to the first exemplary embodiment.

FIG. 2 shows a flowchart of an example of a flow of processing for determining a threshold value of geochemical anomalies in the crust data analysis device according to the first exemplary embodiment.

FIG. 3 shows sampling locations in an existing area applied as a first area according to the first exemplary embodiment.

FIG. 4A shows a frequency distribution of analytical values of lead.

FIG. 4B shows a cumulative frequency distribution of the analytical values of lead.

FIG. 4C shows sampling locations that were decided to have anomalous values on the basis of the threshold value of geochemical anomalies of the crustal abundances of lead.

FIG. 5A shows a frequency distribution of the analytical values of zinc.

FIG. 5B shows the cumulative frequency distribution of the analytical values of zinc.

FIG. 5C shows the sampling locations that were decided to have the anomalous values on the basis of the threshold value of geochemical anomalies of the crustal abundances of zinc.

FIG. 6A shows the frequency distribution of the analytical values of silver.

FIG. 6B shows the cumulative frequency distribution of the analytical values of silver.

FIG. 6C shows the sampling locations that were decided to have the anomalous values on the basis of the threshold value of geochemical anomalies of the crustal abundances of silver.

FIG. 7A shows the frequency distribution of the analytical values of sulfur.

FIG. 7B shows the cumulative frequency distribution of the analytical values of sulfur.

FIG. 7C shows the sampling locations that were decided to have the anomalous values on the basis of the threshold value of geochemical anomalies of the crustal abundances of sulfur.

FIG. 8 shows the flowchart of an example of a flow of processing for determining the threshold value of geochemical anomalies in the crust data analysis device according to the second exemplary embodiment.

FIG. 9 shows an example of the frequency distribution of the background values and the anomalous values of a plurality of samples gathered from a crust.

FIG. 10 shows the cumulative frequency distribution of the analytical values of each element in each of the plurality of samples.

FIG. 11A shows the frequency distribution of analytical values of Au (gold) in the Kushikino Deposit which is a typical mineral deposit area in Hokusatsu and Nansatsu.

FIG. 11B shows the cumulative frequency distribution of the analytical values of Au.

FIG. 11C shows the sampling locations (black dots in the map) that were decided to have the anomalous values by the present technique.

FIG. 11D shows the sampling locations (black dots in the map) that were decided to have the anomalous values by the conventional technique.

DETAILED DESCRIPTION OF THE INVENTION

[0021] <First Exemplary Embodiment>

[Configuration Example of Crust Data Analysis Device 1]

FIG. 1 shows a functional configuration of a crust data analysis device 1 according to the present exemplary embodiment. The crust data analysis device 1 determines a threshold value (hereinafter, referred to as a threshold value of geochemical anomalies) for classifying crustal abundance information that contains a plurality of pieces of data indicating the crustal abundance of each of a plurality of elements or compounds (hereinafter, referred to as elements and the like) obtained by analyzing samples gathered at a plurality of positions in a first area into a background population and an anomalous population. Hereinafter, the plurality of pieces of data is referred to as the object data.

[0022] Specifically, the crust data analysis device 1 generates non-deleted data by deleting data in which the crustal abundance is equal to or greater than a first threshold value from the object data. Then, the crust data analysis device 1 keeps changing the first threshold value until the non-deleted data comes to have a normal distribution in which the average value is the average crustal abundance in a second area that is wider than the first area, and determines the largest crustal abundance value in the non-deleted data with the smallest number of pieces of data within the non-deleted data to be the threshold value of geochemical anomalies. As the average crustal abundance in the second area, for example, the average chemical composition data of the upper continent crust disclosed in Rudnick, R.L. and Gao, S. (2003) The Composition of the Continental Crust, p1-64. In The Crust (ed. R.L. Rudnick) Vol. 3, Treatise on Geochemistry (eds. H.D. Holland and K.K. Turekian), Elsevier-Pergamon, Oxford can be used.

[0023] Hereinafter, a specific configuration of the crust data analysis device 1 is described. The crust data analysis device 1 includes a display section 10, an inputting section 20, a storage section 30, and a controlling section 40. The display section 10 contains, for example, a liquid crystal display. The display section 10 displays various pieces of information in response to control by the controlling section 40. The inputting section 20 contains, for example, a mouse and a keyboard. The inputting section 20 accepts an input of various pieces of information from a user and outputs the accepted information to the controlling section 40.

[0024] The storage section 30 contains, for example, a ROM, a RAM, a hard disk, and the like. The storage section 30 stores various programs (not shown in the figure) for operating the crust data analysis device 1. Specifically, the storage section 30 stores a crust data analysis program for causing the controlling section 40 to operate as an acquiring section 41, a generating section 42, a deciding section 43, and a determining section 44 as mentioned below. Further, the crust analysis program may be stored in a storage medium such as a CD-ROM and a hard disk, and the storage section 30 may store the crust data analysis program acquired from the storage medium.

[0025] Furthermore, the storage section 30 stores, for example, the object data. Moreover, the storage section 30 stores the average chemical composition data indicating the average crustal abundance of each of the plurality of elements and the like measured at the plurality of positions in the second area that is wider than the first area. Further, in the present exemplary embodiment, the second area includes the first area.

[0026] The controlling section 40 contains, for example, a central processing unit (CPU). The controlling section 40 controls functions of the crust data analysis device 1 by executing various programs for operating the crust data analysis device 1 stored in the storage section 30. Specifically, the controlling section 40 causes a computer to operate as the acquiring section 41, the generating section 42, the deciding section 43, and the determining section 44 by executing the crust data analysis program stored in the storage section 30. Hereinafter, the acquiring section 41, the generating section 42, the deciding section 43, and the determining section 44 are described.

[0027] The acquiring section 41 acquires, for example, the object data from the storage section 30. That is, the acquiring section 41 acquires a plurality of pieces of data indicating the crustal abundances of the predetermined elements or compounds at a plurality of positions previously stored in the storage section 30. Here, the predetermined elements or compounds are elements or compounds from which the threshold value between the background population and the anomalous population is detected.

[0028] The generating section 42 generates a plurality of pieces of non-deleted data by deleting a portion of data from among a plurality of pieces of data. Specifically, the generating section 42 generates the plurality of pieces of non-deleted data by deleting data in which the crustal abundance is equal to or greater than a first threshold value from the object data acquired by the acquiring section 41 by using each different first threshold value. More specifically, the generating section 42 sets the largest crustal abundance among the crustal abundances indicated by the object data to be the first threshold value, and generates the non-deleted data by deleting the data that is equal to or greater than the first threshold value from the object data. Then, in a case where the first threshold value is reset as a result of the decision of the deciding section 43, the generating section 42 sets the second largest crustal abundance among the crustal abundances indicated by the object data to be the first threshold value, and generates the non-deleted data by deleting the data that is equal to or greater than the first threshold value from the object data.

[0029] Further, a plurality of pieces of data indicating a plurality of each different values may be previously stored in the storage section 30 as a data set of the first threshold values, and the generating section 42 may extract data in order beginning with higher values from the data set and set the value of the extracted data to be the first threshold value.

[0030] Here, the generating section 42 may generate the plurality of pieces of non-deleted data by deleting data in which the crustal abundance of the plurality of pieces of data is equal to or greater than the first threshold value from the object data by using each different first threshold value and by deleting data that is equal to or less than the second threshold value from the object data by using the second threshold value that is less than the first threshold value. Further, the second threshold value is a detection limit value of the crustal abundances in the object data. Furthermore, the generating section 42 may generate the non-deleted data by deleting the data that is equal to or greater than the first threshold value after deleting the data that is equal to or less than the second threshold value from the object data.

[0031] With respect to each of the plurality of pieces of non-deleted data, the deciding section 43 decides whether or not a plurality of pieces of data constituting the non-deleted data has a normal distribution. The deciding section 43 decides whether or not the plurality of pieces of data constituting the non-deleted data has a normal distribution in which the average value is the average crustal abundance of the predetermined elements in the second area. Here, the predetermined elements denote elements or compounds from which the threshold value between the background population and the anomalous population is detected.

[0032] First, the deciding section 43 acquires average crustal abundance μ of the predetermined elements from the average chemical composition data stored in the storage section 30. Then, the deciding section 43 builds up a null hypothesis that the average value of the crustal abundances of the plurality of pieces of data constituting the non-deleted data is the average crustal abundance μ of the predetermined elements in the second area. Subsequently, the deciding section 43 calculates the average value x_{bar}, the dispersion S^2, and the verification statistic t of the crustal abundances of the plurality of pieces of data constituting the non-deleted data on the basis of the following equations (1) to (3). Here, the number of the plurality of pieces of data constituting the non-deleted data is n, and the crustal abundances of each of the plurality of pieces of data are x_i (where, i is an integer from 1 to n).

[0033]

[Equation 1]

$$x_{bar} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad \cdot\cdot\cdot (1)$$

[Equation 2]

$$s^2 = \frac{1}{n}\sum_{i=1}^{n} \{(x_i - x_{bar})^2\} \quad \cdot\cdot\cdot (2)$$

[Equation 3]

$$t = (x_{bar} - \mu) \Big/ \sqrt{\frac{S^2}{(n-1)}} \quad \cdot\cdot\cdot (3)$$

[0034] Subsequently, the deciding section 43 specifies the boundary value $t_{(n-1)}(0.05)$ of the t distribution with n-1 degrees of freedom from the t distribution chart previously stored in the storage section 30, and decides whether or not an absolute value of the verification statistic t is larger than the boundary value. When the absolute value of the verification statistic t is decided to be greater than the boundary value, the deciding section 43 adopts an alternative hypothesis and decides that the non-deleted data does not have a normal distribution in which the average value is the average crustal abundance of the predetermined elements in the second area. Further, when the absolute value of the verification statistic t is decided to be equal to or less than the boundary value, the deciding section 43 rejects the alternative hypothesis and decides that the non-deleted data has a normal distribution in which the average value is the average crustal abundance of the predetermined elements in the second area.

[0035] The determining section 44 determines the threshold value of geochemical anomalies on the basis of a result of the decision. Specifically, the determining section 44 determines the largest crustal abundance value in the non-deleted data with the smallest number of pieces of data among the plurality of pieces of non-deleted data that is decided not to have a normal distribution to be the threshold value of geochemical anomalies.

[0036]

[Processing Flow]

Next, a flow of processing of the controlling section 40 is described. FIG. 2 shows a flowchart of an example of the flow of the processing for determining the threshold value of geochemical anomalies in the crust data analysis device 1 according to the first exemplary embodiment.

[0037] First, the acquiring section 41 acquires the object data stored in the storage section 30 (S1). Then, the generating section 42 deletes the data in which the crustal abundance is equal to or less than the second threshold value from the object data acquired in S1 (S2).

[0038] Subsequently, the generating section 42 determines the first threshold value (S3). For example, when the number of executions of the processing is 1, that is, when the processing is executed for the first time, the generating section 42 determines the largest crustal abundance in the object data to be the first threshold value. Further, when the number of executions of the processing is equal to or greater than 2, the generating section 42 determines the next largest crustal abundance from the crustal abundance corresponding to the last decided first threshold value to be new first threshold value in the object data.

[0039] Then, the generating section 42 generates the non-deleted data by deleting the data that is equal to or greater than the first threshold value from the object data (S4). Subsequently, the deciding section 43 decides whether or not the non-deleted data has a normal distribution in which the average value is the average crustal abundance of the predetermined elements in the second area (S5). When the deciding section 43 decides that the non-deleted data has a normal distribution (a decision of Yes in S5), the process proceeds to S6. Further, when the deciding section 43 decides that the non-deleted data does not have a normal distribution (a decision of No in S5), the process proceeds to S1.

[0040] Subsequently, the determining section 44 specifies the non-deleted data with the smallest number of pieces of data, that is, the last generated non-deleted data among the plurality of pieces of non-deleted data that is generated in S4 and is decided not to have a normal distribution. Then, the determining section 44 determines the largest crustal abundance value in the specified non-deleted data to be the threshold value of geochemical anomalies (S6).

[0041]

[Example of an application to actual data]

FIG. 3 shows sampling locations in an existing area (the Toyoha Deposit) applied as a first area according to the first exemplary embodiment. The sampling locations shown in FIG. 3 are the 184 points in the Toyoha Deposit disclosed in Non-Patent Document 2. The analytical values of rock samples gathered on the surface of the earth at these points disclosed in Non-Patent Document 2 were used as the object data for which the technique according to the present exemplary embodiment was applied. The black spots shown in FIG. 3 are the sampling locations of the samples. Here, the threshold value of geochemical anomalies of each element was determined on the basis of the amount of contents of lead (Pb), zinc (Zn), silver (Ag), and sulfur (S) obtained by analyzing the plurality of rock samples gathered at the above-mentioned points.

[0042] FIG. 4A shows a frequency distribution of the analytical values of lead (Pb). The horizontal axis in FIG. 4A represents values of a common logarithm of the crustal abundances of Pb.

FIG. 4B shows a cumulative frequency distribution of the analytical values of lead. The horizontal axis in FIG. 4B represents the crustal abundances of Pb and the vertical axis represents an inverse function of the normal distribution probability. FIG. 4C shows sampling locations decided to have anomalous values on the basis of a threshold value of geochemical anomalies of the crustal abundances of lead. In FIG. 4C, the black spots having the same size as the black spots shown in FIG. 3 represent the sampling locations in which the crustal abundances of Pb were 1.5-16 ppm, the white spots represent the sampling locations in which the crustal abundances of Pb were 17-24 ppm, and the black dots that are larger than the black spots represent the sampling locations in which the crustal abundances of Pb were 25-70 ppm.

[0043] With respect to the crustal abundances of Pb in the first area, the highest value was 70 ppm, the lowest value was 1.5 ppm, and the average value x_{bar} of the plurality of pieces of data was 5.2 ppm. Further, the average value of the crustal abundances of Pb in the average chemical composition data stored in the storage section 30 was 17 ppm. As a result of the crust data analysis device 1 calculating the threshold value of geochemical anomalies on the basis of these results, the threshold value was 25 ppm.

In the first area, 10 points were obtained as the points of geochemical anomalies higher than 25 ppm. Further, the points where samples having the crustal abundances identical to the threshold value of geochemical anomalies were gathered might be the points of geochemical anomalies. Accordingly, it is understood that the points showing the geochemical anomalies can be extracted according to the technique of the present exemplary embodiment even when the cumulative frequency distribution map shows an almost straight line as shown in FIG. 4B.

[0044] FIG. 5A shows the frequency distribution of the analytical values of zinc (Zn). FIG. 5B shows the cumulative frequency distribution of the analytical values of zinc. FIG. 5C shows the sampling locations decided to have the anomalous values on the basis of the threshold value of geochemical anomalies of the crustal abundances of zinc. The black spots in FIG. 5C represent the sampling locations in which the crustal abundances of Zn were 0.5-66 ppm, the white spots represent the sampling locations in which the crustal abundances of Zn were 67-96 ppm, and the black dots represent the sampling locations in which the crustal abundances of Zn were 97-370 ppm.

[0045] With respect to the crustal abundances of Zn in the first area, the highest value was 370 ppm, the lowest value was 0.5 ppm, and the average value x_{bar} of the plurality of pieces of data was 45.9 ppm. Further, the average value of the crustal abundances of Zn in the average chemical composition data stored in the storage section 30 was 67 ppm. As a result of the crust data analysis device 1 calculating the threshold value of geochemical anomalies on the basis of these results, the threshold value was 97 ppm. In the first area, 23 points were obtained as the points of geochemical anomalies higher than 97 ppm.

[0046] FIG. 6A shows the frequency distribution of the analytical values of silver (Ag). FIG. 6B shows the cumulative frequency distribution of the analytical values of silver. FIG. 6C shows the sampling locations decided to have the anomalous values on the basis of the threshold value of geochemical anomalies of the crustal abundances of silver. The black spots in FIG. 6C represent the sampling locations in which the crustal abundances of Ag were equal to or less than 0.1 ppm and the black dots represent the sampling locations in which the crustal abundances of Ag were 0.2-6.2 ppm.

[0047] With respect to the crustal abundances of Ag in the first area, the highest value was 6.2 ppm, the lowest value was 0.1 ppm, and the average value x_{bar} of the plurality of pieces of data was 0.2 ppm. Further, the detection limit of Ag was 0.2 ppm. Furthermore, the average value of the crustal abundances of Ag in the average chemical composition data stored in the storage section 30 was 53 ppb. As a result of the crust data analysis device 1 calculating the threshold value of geochemical anomalies on the basis of these results, 0.2 ppm that was the detection limit value was determined to be the threshold value of geochemical anomalies because the non-deleted data without deleting the data of 0.2 ppm does not have a normal distribution of the crustal abundances with the average value 53 ppb. Consequently, in the first area, 35 points were obtained as the points of geochemical anomalies higher than 0.2 ppm that was the detection limit value.

[0048] FIG. 7A shows the frequency distribution of the analytical values of sulfur (S). FIG. 7B shows the cumulative frequency distribution of the analytical values of sulfur. FIG. 7C shows the sampling locations decided to have the anomalous values on the basis of the threshold value of geochemical anomalies of the crustal abundances of sulfur. The black spots in FIG. 7C represent the sampling locations in which the crustal abundances of S were 0.005-0.05 ppm, the white spots represent the sampling locations in which the crustal abundances of S were 0.06-0.09 ppm, and the black dots represent the sampling locations in which the crustal abundances of S were 0.1-4.41 ppm.

[0049] With respect to the crustal abundances of S in the first area, the highest value was 4.41%, the lowest value was 0.005%, and the average value x_{bar} of the plurality of pieces of data was 0.2%. Further, the average amount of content of the crustal abundances of S in the average chemical composition data stored in the storage section 30 was 0.06%. As a result of the crust data analysis device 1 calculating the threshold value of geochemical anomalies on the basis of these results, 0.1% was determined to be the threshold value of geochemical anomalies and 109 points were obtained as the points of geochemical anomalies.

[0050]

[Comparative Example]

Subsequently, with respect to the amount of content of each element in the samples gathered at the 163 points in the existing area applied as the first area, the threshold value of geochemical anomalies was determined by using another technique. Here, an example where the threshold values of the geochemical anomalies of Pb, Zn, Ag, and S were determined by the technique that determines a threshold value with a multiple of a value obtained by adding a standard deviation to an average value in a common logarithm proposed by the Ministry of International Trade and Industry in 1986 (hereinafter, referred to as the technique of the MITI) is described.

[0051] With respect to Pb, the average value was 5.2 ppm, the average value + the standard deviation was 13.2 ppm, and the average value + 2 × the standard deviation was 33.4 ppm.

In this case, it is considered that there is no wide difference in appearances of the geochemical anomalies between the technique with the crust data analysis device 1 and the technique of the MITI that determines the threshold value with a multiple of a value obtained by adding a standard deviation to an average value in a common logarithm.

[0052] With respect to Zn, the average value was 45.9 ppm, the average value + the standard deviation was 146.6 ppm, and the average value + 2 × the standard deviation was 468.0 ppm. The value that was equal to or greater than the average value + 2 × the standard deviation did not exist in the object data. Further, the average value 45.9 ppm was smaller than the average value 67 ppm of the crustal abundances indicated by the average chemical composition data of the upper continent crust. Accordingly, the technique of the MITI cannot detect the anomalous population that could be detected by the technique using the crust data analysis device 1.

[0053] With respect to Ag, the average value was 0.2 ppm, the average value + the standard deviation was 0.4 ppm, and the average value + 2 × the standard deviation was 0.9 ppm. Here, there were 25 points with a value larger than 0.4 ppm and there were 9 points with a value larger than 0.9 ppm. The potential vein of the geochemical anomalies can be obtained with the technique of the MITI but there are cases where the threshold value is not appropriately determined because the threshold value of geochemical anomalies is determined without considering the detection limit. Accordingly, it is considered that a method for determining the threshold value of geochemical anomalies by the crust data analysis device 1 shows the presence of the geochemical anomalies more precisely than the technique of the MITI.

[0054] With respect to S, the average value was 0.2%, the average value + the standard deviation was 1.1%, and the average value + 2 × the standard deviation was 6.1%. The value 6.1% was a crustal abundance that did not exist in the samples and was far larger than the average value of the crustal abundances shown in the average chemical composition data. Accordingly, it can be said that the threshold value of geochemical anomalies of S cannot be appropriately determined with the technique of the MITI. On the other hand, as mentioned above, the method that determines the threshold value of geochemical anomalies with the crust data analysis device 1 obtained 109 points as the points of geochemical anomalies. Accordingly, with this result, it can be considered that the method that determines the threshold value of geochemical anomalies with the crust data analysis device 1 detects the points where the geochemical anomalies occur more precisely than the technique of the MITI.

[0055]

[Verification of Normal Distribution]

Next, a result of the verification of whether the average chemical composition of main igneous rocks of the crust has a normal distribution in which the average value is the crustal abundance is described. Specifically, assuming that the average chemical composition of the main igneous rocks has a normal distribution with the average crustal abundance μ in the second area, a confidence interval with a 95% confidence coefficient of a population variance was found and the value of $\mu + \sigma$ by the largest standard deviation σ was calculated. For example, with respect to SiO_2, the result that 93.1% was close to the maximum value in the normal population in which the average value was the crustal abundance was shown. This value roughly corresponded to a value of strong silicified rocks. Further, with respect to MgO, the result that 25.9% was close to the maximum value in the normal population in which the average value was the crustal abundance was shown. It can be considered that the value 25.9 is reasonable because MgO contained in the liquid of the partial melting of the mantle reached 20% or more. Accordingly, it was shown that the average chemical composition in the main igneous rocks of the crustal had a normal distribution in which the average value was the crustal abundance.

[0056]

[Effect of First Exemplary Embodiment]

As described above, the crust data analysis device 1 according to the present exemplary embodiment decides whether or not the plurality of pieces of data constituting the non-deleted data has a normal distribution and determines the threshold value of geochemical anomalies on the basis of a result of the decision for each of the plurality of pieces of non-deleted data from the plurality of pieces of data. Accordingly, the crust data analysis device 1 can classify the plurality of pieces of non-deleted data into the background population and the anomalous population by classifying the plurality of pieces of non-deleted data into the non-deleted data that has a normal distribution and the non-deleted data that does not have a normal distribution, and can appropriately set the threshold value of geochemical anomalies on the basis of the boundary value of these populations.

[0057] Further, the crust data analysis device 1 generates the plurality of pieces of non-deleted data by deleting the data in which the crustal abundance is equal to or greater than the first threshold value from the plurality of pieces of data by using each different first threshold value, decides whether or not the plurality of pieces of data constituting the non-deleted data has a normal distribution in which the average value is the average crustal abundance of the predetermined elements in the second area that is wider than the first area, and determines the largest crustal abundance value in the non-deleted data with the smallest number of pieces of data among the plurality of pieces of non-deleted data that was decided not to have a normal distribution to be the threshold value of geochemical anomalies.

[0058] Accordingly, the crust data analysis device 1 can appropriately set the threshold value of geochemical anomalies for classifying the plurality of pieces of data into the population that has a normal distribution in which the average value is the average crustal abundance of the predetermined elements in the second area that is wider than the first area and the population that does not have a normal distribution.

[0059] Furthermore, in a step for generating the plurality of pieces of non-deleted data, the crust data analysis device 1 generates the plurality of pieces of non-deleted data by deleting the data in which the crustal abundances of the plurality of pieces of data is equal to or greater than the first threshold value by using each different first threshold value and by deleting data that is equal to or less than the second threshold value by using the second threshold value that is less than the first threshold value from the plurality of pieces of data. That is, the crustal data analysis device 1 generates the non-deleted data by deleting the data that is equal to or greater than the first threshold value after deleting the data that is equal to or less than the second threshold value indicating the detection limit of the crustal abundances from the non-deleted data. Consequently, because the crust data analysis device 1 decides whether or not the non-deleted data generated by deleting crustal abundances less than the detection limit has a normal distribution, the crust data analysis device 1 can accurately decide the threshold value of geochemical anomalies.

[0060] <Second Exemplary Embodiment>

[Determining first threshold value by using binary search]

Next, the second exemplary embodiment is described. It is different from the first exemplary embodiment in a point that the generating section 42 of the present exemplary embodiment determines the first threshold value on the basis of a binary search and generates the non-deleted data on the basis of the determined first threshold value, and is the same as the first exemplary embodiment with respect to the other points.

[0061] Specifically, the generating section 42 rearranges the non-deleted data in order beginning with the lowest crustal abundance. Subsequently, the generating section 42 sets a search range of the first threshold value that is from the data corresponding to the crustal abundance that is closest to the average crustal abundance to the data with the largest crustal abundance. Next, the generating section 42 determines the median value of the search range to be an initial value of the first threshold value. Then, the generating section 42 generates the non-deleted data by deleting the data that is equal to or greater than the determined first threshold value from the object data. And then, the deciding section 43 decides whether or not the non-deleted data has a normal distribution in which the average value is the average crustal abundance of the predetermined elements in the second area.

[0062] The generating section 42 reduces a new search range of the first threshold value into half of the last search range and determines a new first threshold value on the basis of a result of the decision of the deciding section 43. Specifically, when the deciding section 43 decides that the non-deleted data has a normal distribution, the generating section 42 sets a range larger than the first threshold value in the present search range to be the new search range. Further, when the deciding section 43 decides that the non-deleted data does not have a normal distribution, the generating section 42 sets a range smaller than the first threshold value in the present search range to be the new search range. Subsequently, the generating section 42 determines the median value of the newly-set search range to be the new first threshold value. Then, the generating section 42 generates the non-deleted data by deleting the data that is equal to or greater than the determined first threshold value.

[0063] The generating section 42 repeats the process of generating the non-deleted data by determining the first threshold value until the search range cannot be reduced. After the generating section 42 finishes the process of generating the non-deleted data, the determining section 44 determines the largest crustal abundance value in the non-deleted data with the smallest number of pieces of data among the plurality of pieces of non-deleted data that was decided not to have a normal distribution to be the threshold value of geochemical anomalies.

[0064]

[Processing flow]

Next, a flow of processing of the controlling section 40 is described. FIG. 8 shows the flowchart of an example of a flow of processing for determining the threshold value of geochemical anomalies in the crust data analysis device 1 according to the second exemplary embodiment.

[0065] First, the acquiring section 41 acquires the object data stored in the storage section 30 (S11). Subsequently, the generating section 42 deletes the data in which the crustal abundance is equal to or less than the second threshold value from the object data acquired in S11 (S12).

[0066] Then, the generating section 42 determines the search range of the first threshold value and the first threshold value (S13). For example, when the number of executions of the processing is 1, that is, when the processing is executed for the first time, the generating section 42 sets the search range of the first threshold value to be from the data corresponding to the crustal abundance that is closest to the average crustal abundance to the data with the largest crustal abundance. Further, when the number of executions of the processing is equal to or greater than 2, the generating section 42 sets the search range to be half of the last search range on the basis of a result of the last decision of the deciding section 43. Furthermore, the generating section 42 determines the median value of the set search range to be the first threshold value.

[0067] Subsequently, the deciding section 43 decides whether or not the non-deleted data has a normal distribution in which the average value is the average crustal abundance of the predetermined elements in the second area (S15). Then, the generating section 42 decides whether or not the search range of the first threshold value can be reduced (S16). When the generating section 42 decides that the search range can be reduced (a decision of Yes in S16), the process proceeds to S11, and when the generating section 42 decides that the search range cannot be reduced (a decision of No in S16), the process proceeds to S17.

[0068] Subsequently, the determining section 44 specifies the non-deleted data with the smallest number of pieces of data, that is, the last generated non-deleted data among the plurality of pieces of non-deleted data that is generated in S14 and was decided not to have a normal distribution. And then, the determining section 44 determines the largest crustal abundance value in the specified non-deleted data to be the threshold value of geochemical anomalies (S17).

[0069]

[Effect of Second Exemplary Embodiment]

As described above, according to the crust data analysis device 1, because the generating section 42 determines the first threshold value on the basis of the binary search and generates the non-deleted data on the basis of the determined first threshold value, the first threshold value can be efficiently determined and the threshold value of geochemical anomalies can be calculated at a high speed.

[0070] The present invention is described with the exemplary embodiments but the technical scope of the present disclosure is not limited to the scope described in the above embodiments. It is apparent for those skilled in the art that it is possible to make various changes and modifications to the embodiment.

[0071] For example, in the above-mentioned exemplary embodiment, the largest crustal abundance value in the non-deleted data with the smallest number of pieces of data among the plurality of pieces of non-deleted data that was decided not to have a normal distribution is determined to be the threshold value of geochemical anomalies, but other values within a predetermined range from the largest crustal abundance value may be determined to be the threshold value. For example, among the plurality of pieces of non-deleted data that was decided to have a normal distribution, the largest crustal abundance value in the non-deleted data with the largest number of pieces data may be decided to be the threshold value of geochemical anomalies. Further, among the plurality of pieces of non-deleted data that was decided not to have a normal distribution, the value larger than the largest crustal abundance value in the non-deleted data with the smallest number of pieces of data by the predetermined value may be determined to be the threshold value.

[0072] <Third Exemplary Embodiment>

In the first exemplary embodiment, as a partial verification, the method that repeats verifications by deleting the upper and lower data with the crustal abundance value as the center until non-deleted data comes to have a normal distribution, and that obtains the highest value of a population with the smallest number of pieces of data that does not have a normal distribution as the threshold value was described. In the present exemplary embodiment, the threshold value is determined by the following method so as to be applicable to the case where the number of pieces of data increases.

[0073] When the number of pieces of data is n, the deciding section 43 calculates the standard deviation σ as follows, assuming that n pieces of data have the x^2 distribution with n degrees of freedom.

$$\sum_{i=1}^{n}(xi-\mu)^{2}/\ \chi_{n}^{2}(0.025)\ \leqq \sigma^{2} \leqq \sum_{i=1}^{n}(xi-\mu)^{2}/\ \chi_{n}^{2}(0.975)$$

[0074] Subsequently, the deciding section 43 reads a value from the x^2 distribution chart and calculates σ^2. However, when $n>100$, the deciding section 43 calculates σ^2, assuming that the following equation approximately has the standard normal distribution N (0, 1).

$$\sqrt{2\chi^{2}} - \sqrt{2n-1}$$

[0075] By using the minimum standard deviation that was found in this way, the deciding section 43 decides that the values, up to the value obtained by adding the average value and the least standard deviation and by being returned to the real number, have a normal distribution in which the average value is the crustal abundance, and determines the value immediately above this value to be the threshold value. Further, the reason for not using the maximum standard deviation is to reduce redundancy as far as possible because the upper side of the background population and the lower side of the anomalous population are considered to be redundant.

[0076]

[Example of an application to actual data]

On the basis of the amount of contents of Pb, Zn, and S obtained by analyzing the rock samples gathered at the sampling area shown in FIG. 3 with the technique according to the present exemplary embodiment, the threshold value of geochemical anomalies of each element was determined.

[0077] Concerning Pb, the threshold value was 45 ppm and 2 points were obtained as the points of geochemical anomalies. Concerning Zn, the threshold value was 166 ppm and 5 points were obtained as the points of geochemical anomalies. Concerning S, the threshold value was 0.4% and 70 points were obtained as the points of geochemical anomalies.

[0078] The technique according to the present exemplary embodiment is effective especially for the cases where the number of pieces of data is more than 1000. FIG. 11A shows the frequency distribution of analytical values of Au (gold) in the Kushikino Deposit which is a typical mineral deposit area in Hokusatsu and Nansatsu. There were 2331 pieces of data used. FIG. 11B shows the cumulative frequency distribution of the analytical values of Au. FIG. 11C shows the sampling locations (black dots in the map) decided to have the anomalous values on the basis of the threshold value of geochemical anomalies of the crustal abundances of Au found by the present technique.

FIG. 11D shows the sampling locations (black dots in the map) decided to have the anomalous values by the technique of the MITI.

[0079] According to the present technique, the average value of the crustal abundances was 1.5 ppb, the threshold value was 14 ppb, and 132 geochemical anomaly points were obtained. On the other hand, with the technique of the MITI, the average value of the crustal abundances was 2 ppb, the average value + 2 × the standard deviation was 75 ppb, and 65 geochemical anomaly points were obtained. As apparent from a comparison of FIG. 11C and FIG. 11D, a greater number of geochemical anomaly points were found near the deposits by using the present technique.

[0080] A similar comparative analysis was carried out in the Hokuroku region which is a typical deposit in Akita and Aomori. When 3666 pieces of Pb data were used, according to the present technique, the average value of the crustal abundances was 17 ppm, the threshold value was 57 ppm, and 11 geochemical anomaly points were obtained. On the other hand, with the technique of the MITI, the average value of the crustal abundances was 12 ppm, the average value + 2 × the standard deviation was 161 ppm, and 8 geochemical anomaly points were obtained. Accordingly, more geochemical anomaly points were found near the deposits by using the present technique.

[0081] Concerning Zn, a similar comparison was carried out by using 3743 pieces of data. According to the present technique, the average value of the crustal abundances was 67 ppm, the threshold value was 176 ppm, and 12 geochemical anomaly points were obtained. On the other hand, with the technique of the MITI, the average value of the crustal abundances was 65 ppm, the average value + 2 × the standard deviation was 534 ppm, and 2 geochemical anomaly points were obtained. Accordingly, more geochemical anomaly points were found near the deposits by using the present technique.

[0082]

[Effect of Third Exemplary Embodiment]

As described above, according to the technique regarding the third exemplary embodiment, even when the number of pieces of data is large, for example, in the case where the number of pieces of data is equal to or more than 1000, a greater number of geochemical anomaly points can be found near the deposits because the threshold value can be precisely found.

[EXPLANATIONS OF THE REFERENCE NUMERALS]

[0083] 1 crust data analysis device

10 display section

20 inputting section

30 storage section

40 controlling section

41 acquiring section

42 generating section

43 deciding section

44 determining section

CLAIMS

1. A crust data analysis method comprising:

acquiring a plurality of pieces of data indicating crustal abundances of predetermined elements or compounds at a plurality of positions;

generating a plurality of pieces of non-deleted data by deleting a portion of data from the plurality of pieces of data;

deciding whether or not a plurality of pieces of data constituting the non-deleted data has a normal distribution with respect to each piece of the plurality of pieces of non-deleted data; and

determining a threshold value of geochemical anomalies on the basis of a result of the decision.

2. The crust data analysis method according to Claim 1, wherein

the generating the plurality of pieces of non-deleted data generates a plurality of pieces of non-deleted data by deleting data in which the crustal abundances of the plurality of pieces of data is equal to or greater than the first threshold value from the plurality of pieces of data by using each different first threshold value,

the deciding decides whether or not a plurality of pieces of data constituting the non-deleted data has a normal distribution in which an average value is the average crustal abundance of the predetermined elements or compounds in an area that is wider than an area including the plurality of positions, and

the determining the threshold value determines a value within a predetermined range from the largest crustal abundance value in the non-deleted data with the smallest number of pieces of data among the plurality of pieces of non-deleted data that was decided not to have a normal distribution to be the threshold value of geochemical anomalies.

3. The crust data analysis method according to Claim 2, wherein

the generating the plurality of pieces of non-deleted data generates the plurality of pieces of non-deleted data by deleting data in which the crustal abundance of the plurality of pieces of data is equal to or greater than the first threshold value by using each different first threshold value and by deleting data that is equal to or less than a second threshold value by using the second threshold value that is lower than the first threshold value from the plurality of pieces of data.

4. The crust data analysis method according to Claim 3, wherein

the second threshold value is a detection limitation of the crustal abundance, and

the generating the plurality of pieces of non-deleted data generates the non-deleted data by deleting data that is equal to or greater than the first threshold value after deleting the data that is equal to or less than the second threshold value.

5. The crust data analysis method according to any one of Claims 2 to 4, wherein

the generating the plurality of pieces of non-deleted data generates the plurality of pieces of non-deleted data by sequentially reducing the first threshold value, and

the deciding makes the decision after a piece of the non-deleted data is generated.

6. The crust data analysis method according to any one of Claims 2 to 4, wherein

the generating the plurality of pieces of non-deleted data determines the first threshold value on the basis of a binary search and generates the non-deleted data on the basis of the determined first threshold value.

7. A crust data analysis program that causes a computer to operate as:

an acquiring section that acquires a plurality of pieces of data indicating crustal abundances of predetermined elements or compounds at a plurality of positions,

a generating section that generates a plurality of pieces of non-deleted data by deleting a portion of data from the plurality of pieces of data,

a deciding section that decides whether or not a plurality of pieces of data constituting the non-deleted data has a normal distribution with respect to each piece of the plurality of pieces of non-deleted data, and

a determining section that determines a threshold value of geochemical anomalies on the basis of a result of the decision.

8. A crust data analysis device comprising:

an acquiring section that acquires a plurality of pieces of data indicating crustal abundances of predetermined elements or compounds at a plurality of positions;

a generating section that generates a plurality of pieces of non-deleted data by deleting a portion of data from the plurality of pieces of data;

a deciding section that decides whether or not a plurality of pieces of data constituting the non-deleted data has a normal distribution with respect to each piece of the plurality of pieces of non-deleted data; and

a determining section that determines a threshold value of geochemical anomalies on the basis of a result of the decision.

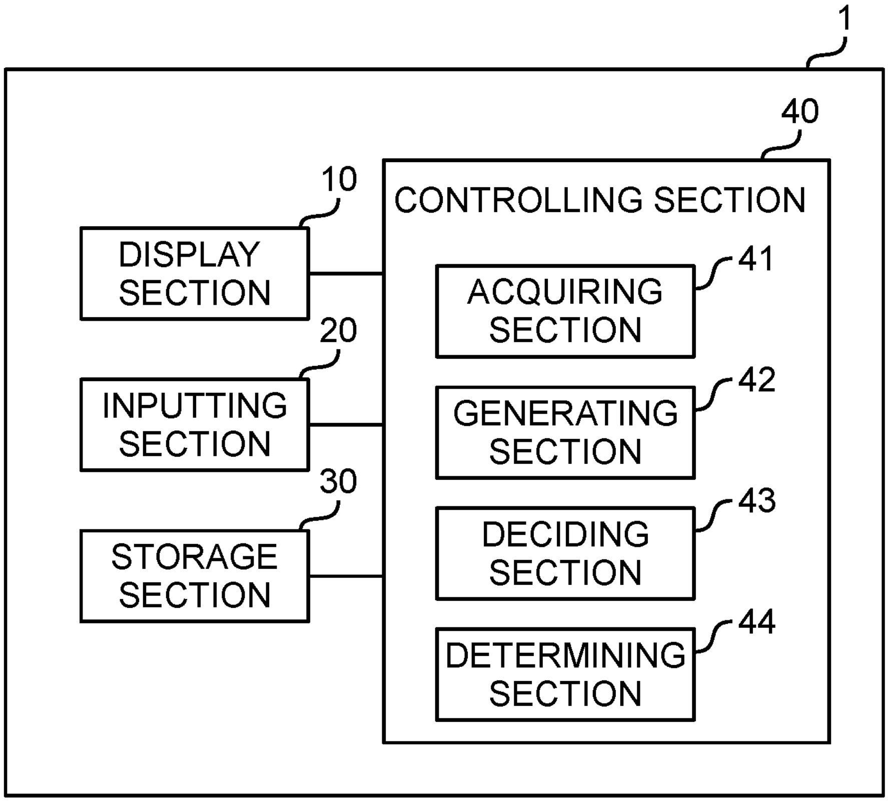

1
40
CONTROLLING SECTION
10
DISPLAY SECTION
41
ACQUIRING SECTION
20
INPUTTING SECTION
42
GENERATING SECTION
30
STORAGE SECTION
43
DECIDING SECTION
44
DETERMINING SECTION

FIG. 1

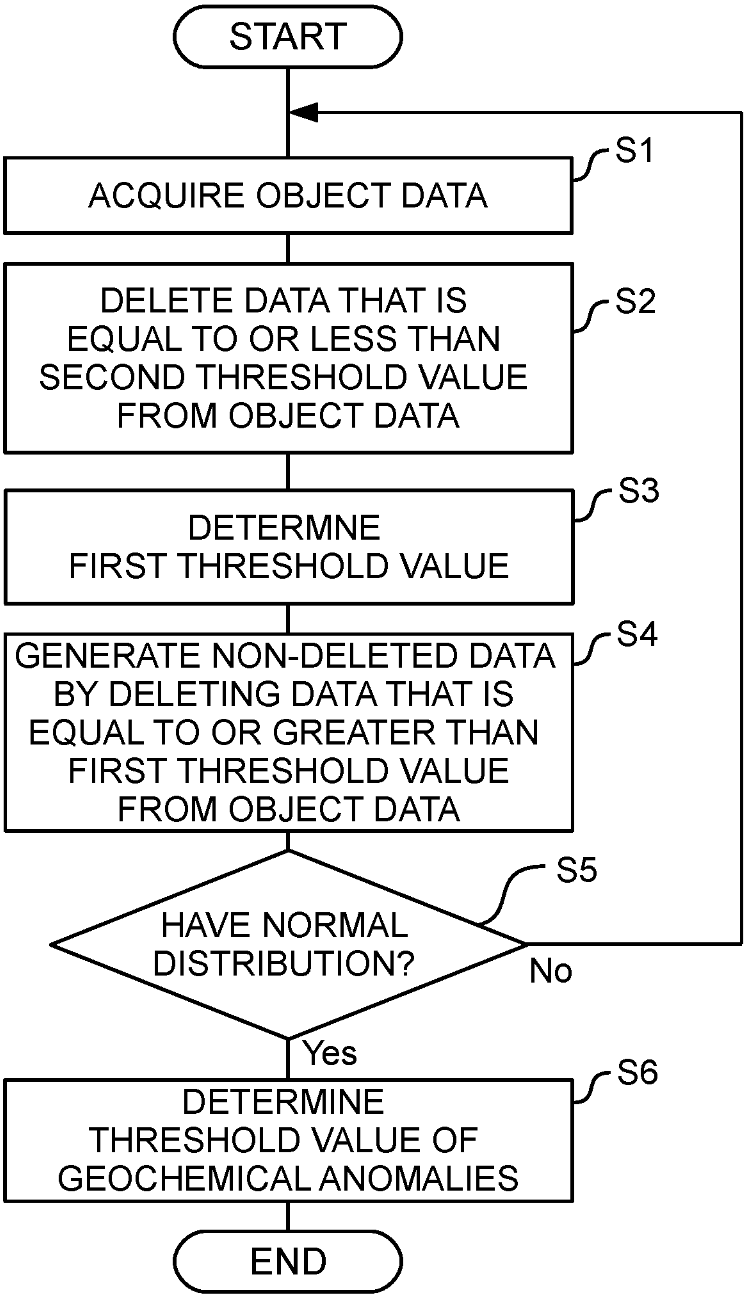

START
ACQUIRE OBJECT DATA
S1
DELETE DATA THAT IS EQUAL TO OR LESS THAN SECOND THRESHOLD VALUE FROM OBJECT DATA
S2
DETERMNE FIRST THRESHOLD VALUE
S3
GENERATE NON-DELETED DATA BY DELETING DATA THAT IS EQUAL TO OR GREATER THAN FIRST THRESHOLD VALUE FROM OBJECT DATA
S4
HAVE NORMAL DISTRIBUTION?
S5
No
Yes
DETERMINE THRESHOLD VALUE OF GEOCHEMICAL ANOMALIES
S6
END

FIG. 2

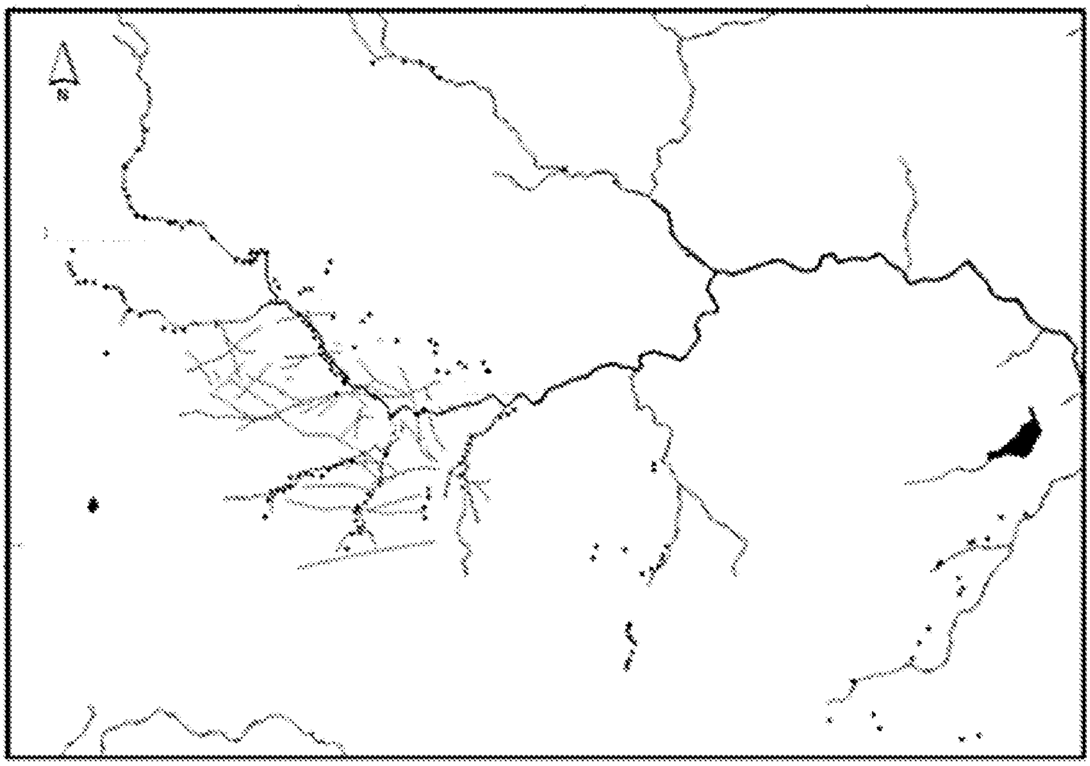


FIG. 3

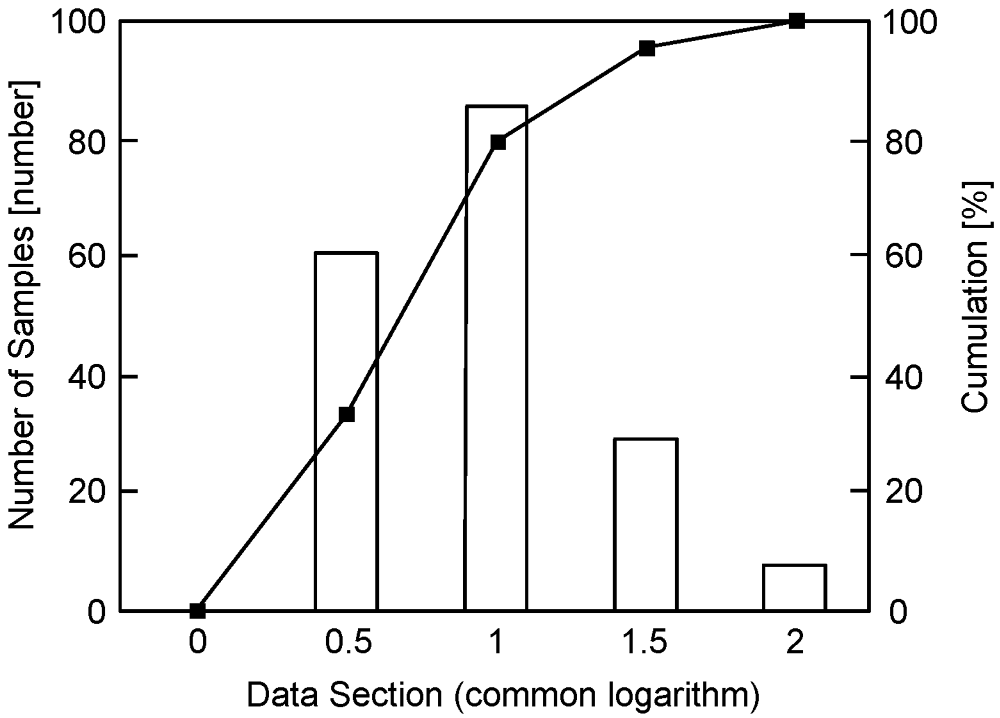

100
80
60
40
20
0
Number of Samples [number]
100
80
60
40
20
0
Cumulation [%]
0
0.5
1
1.5
2
Data Section (common logarithm)

FIG. 4A

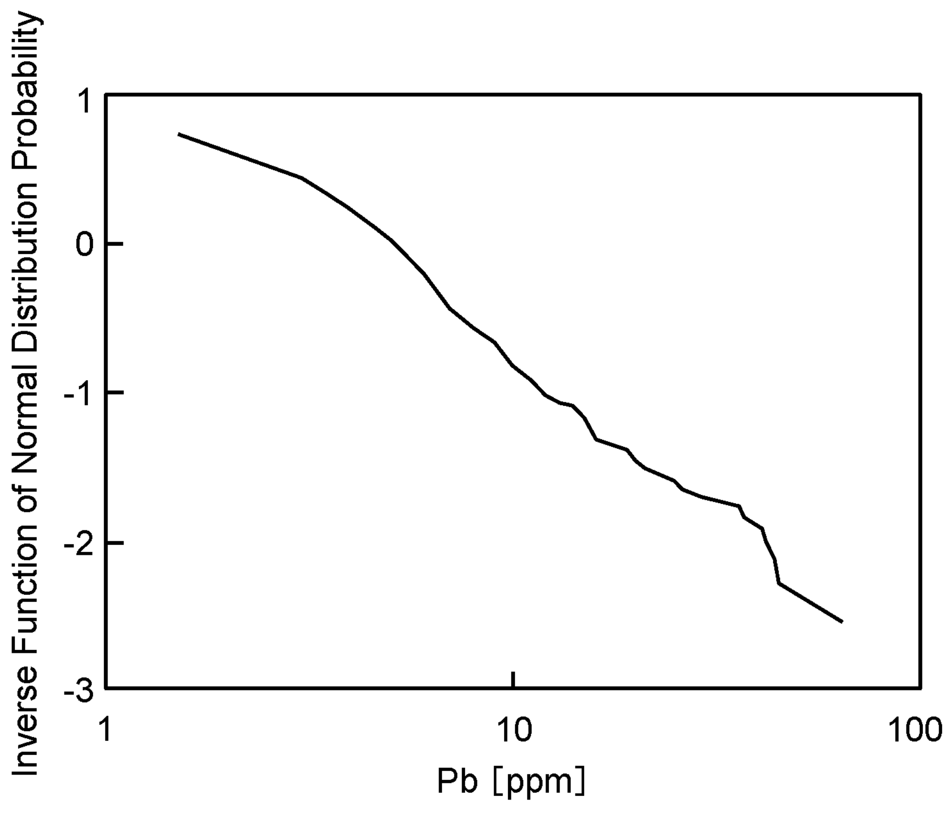

Inverse Function of Normal Distribution Probability
1
0
-1
-2
-3
1
10
100
Pb [ppm]

FIG. 4B

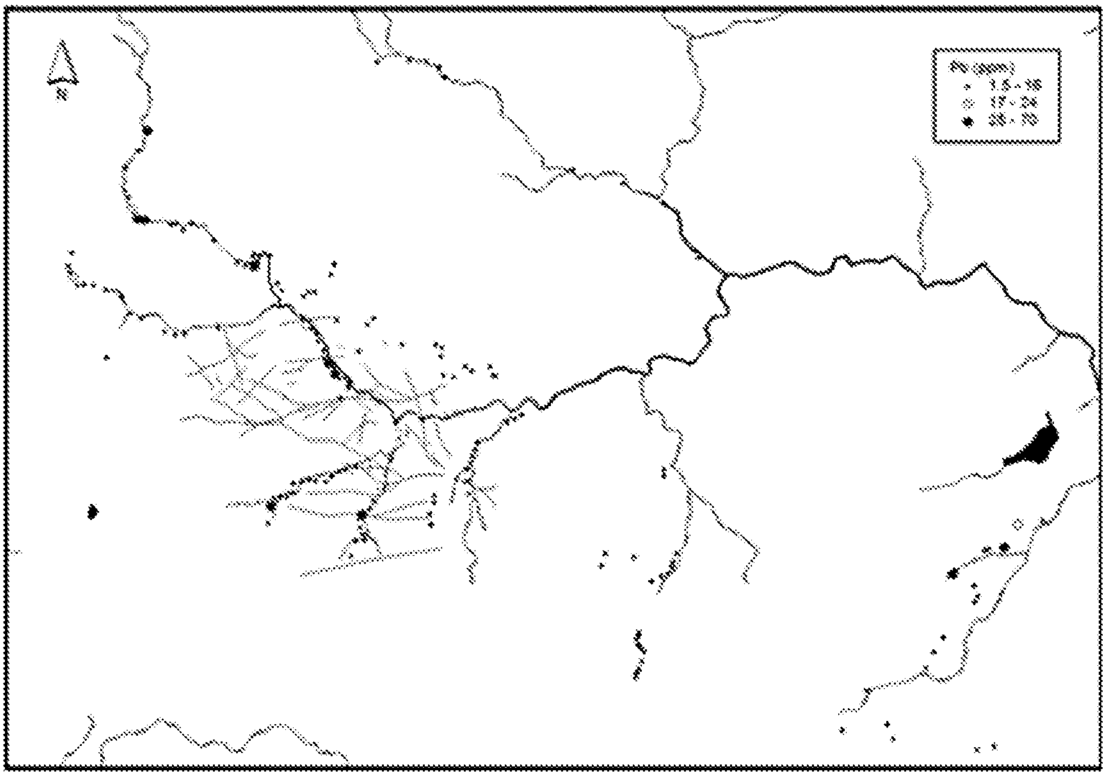


FIG. 4C

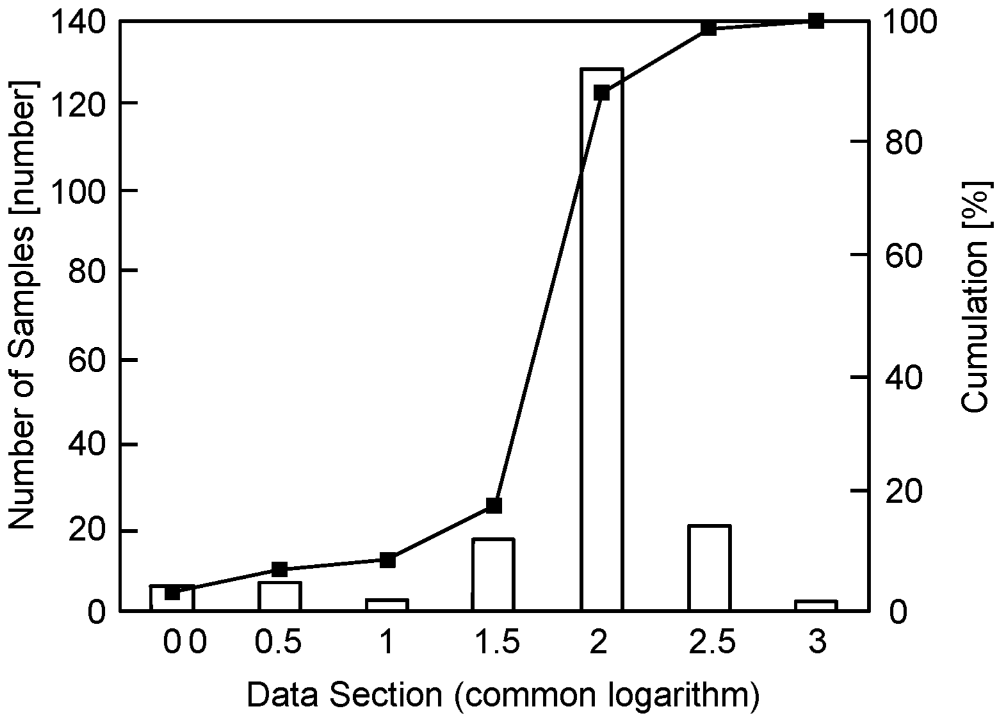

140
120
100
80
60
40
20
0
Number of Samples [number]
100
80
60
40
20
0
Cumulation [%]
0 0
0.5
1
1.5
2
2.5
3
Data Section (common logarithm)

FIG. 5A

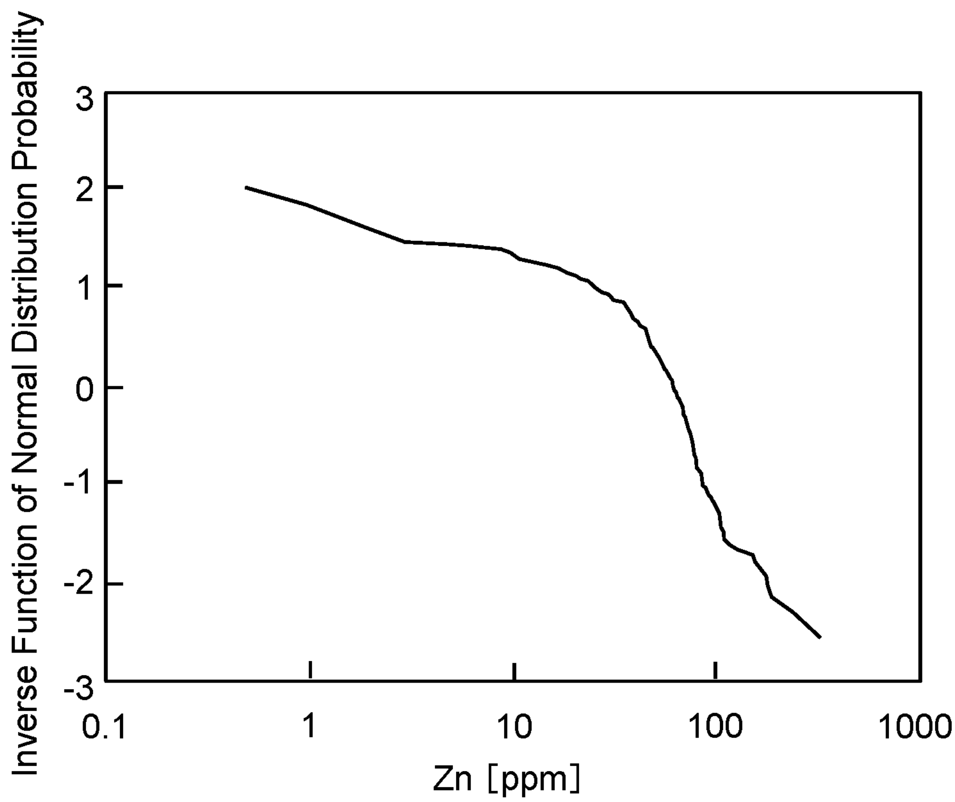

Inverse Function of Normal Distribution Probability
3
2
1
0
-1
-2
-3
0.1
1
10
100
1000
Zn [ppm]

FIG. 5B

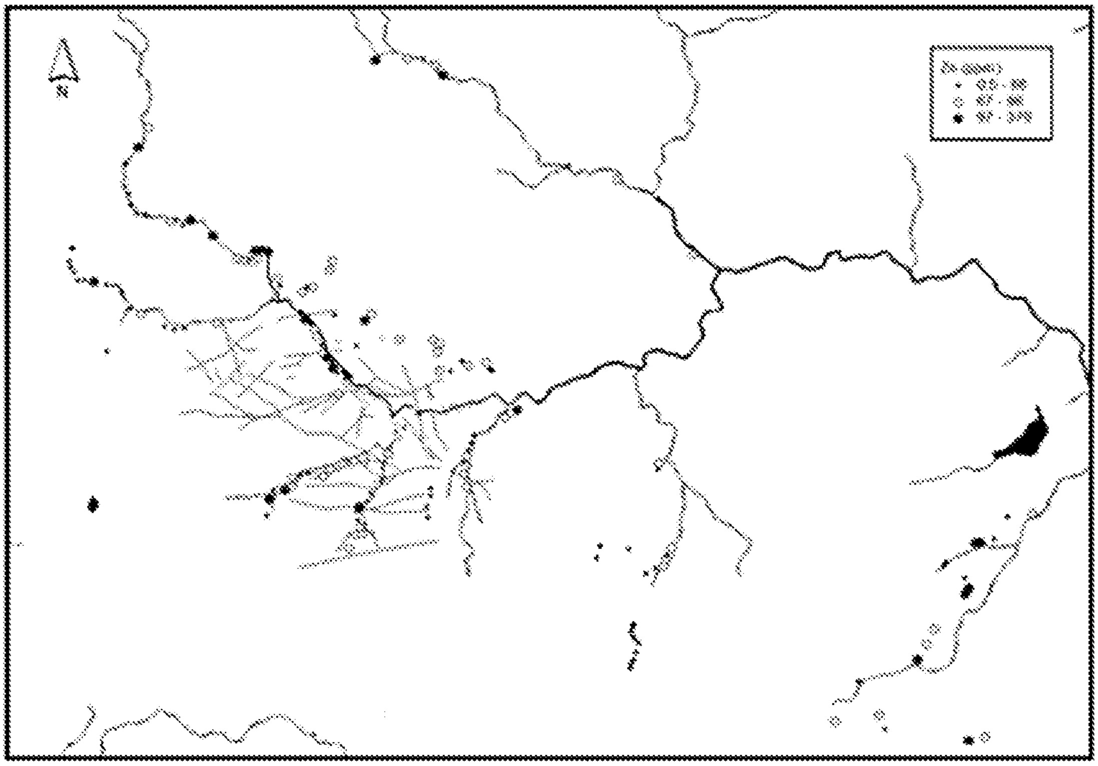


FIG. 5C

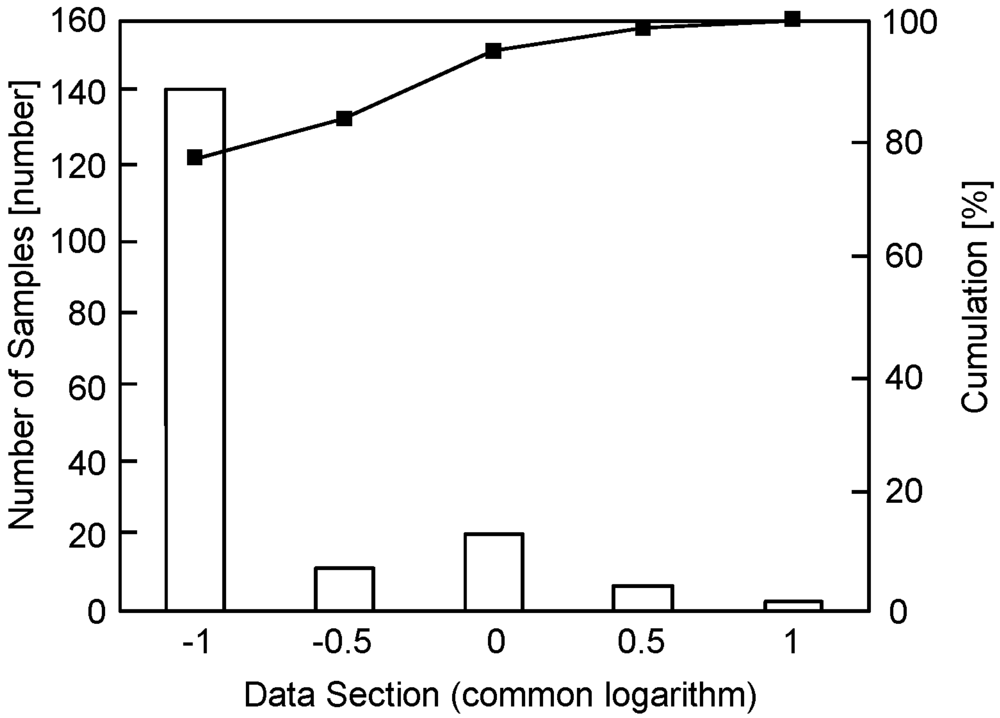

160
140
120
100
80
60
40
20
0
Number of Samples [number]
100
80
60
40
20
0
Cumulation [%]
-1
-0.5
0
0.5
1
Data Section (common logarithm)

FIG. 6A

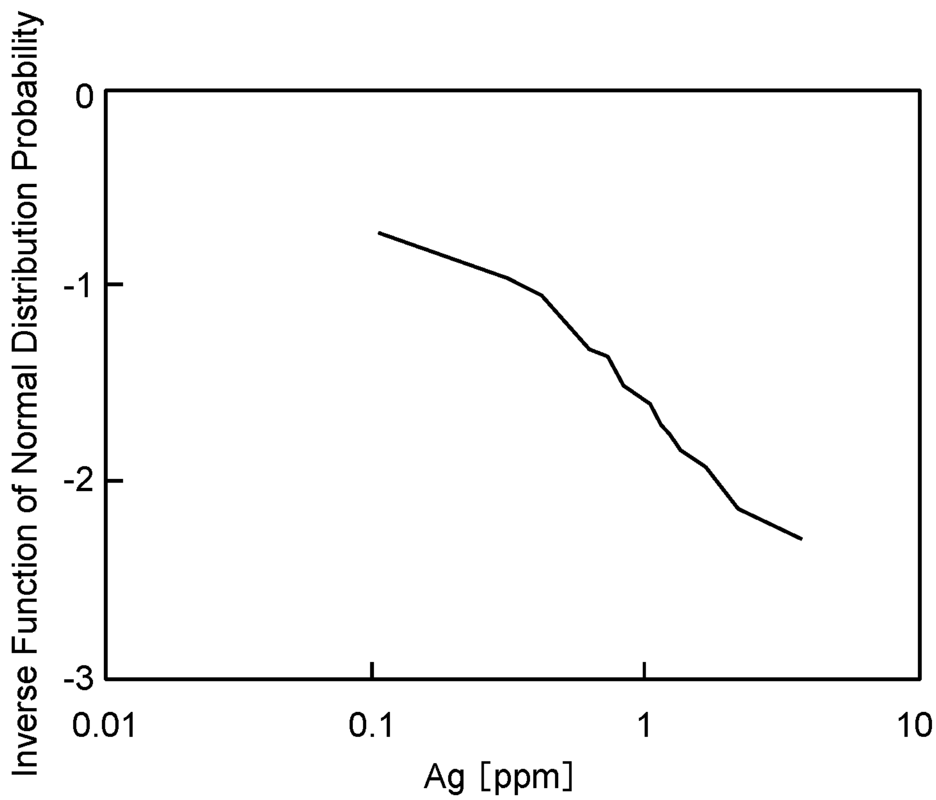

Inverse Function of Normal Distribution Probability
0
-1
-2
-3
0.01
0.1
1
10
Ag [ppm]

FIG. 6B

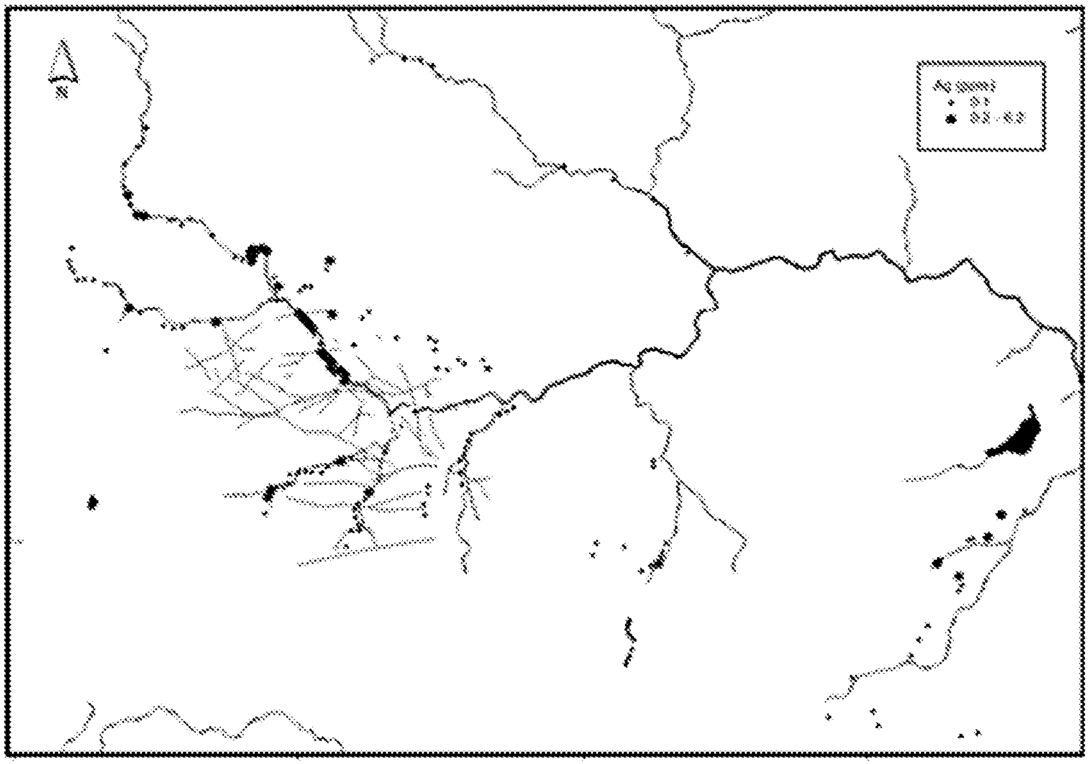
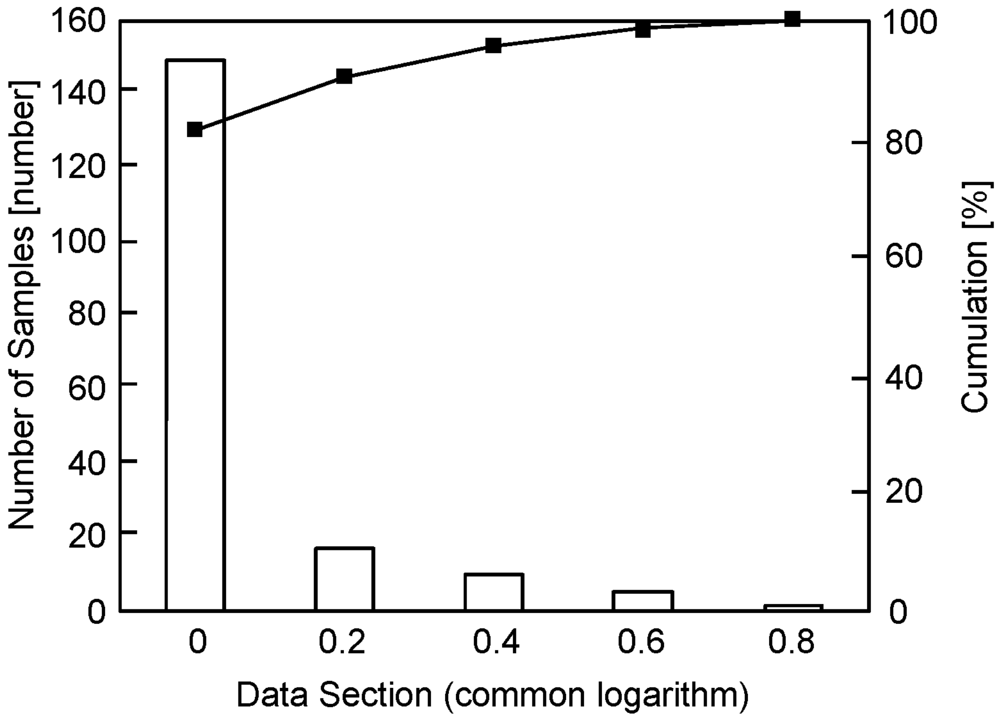
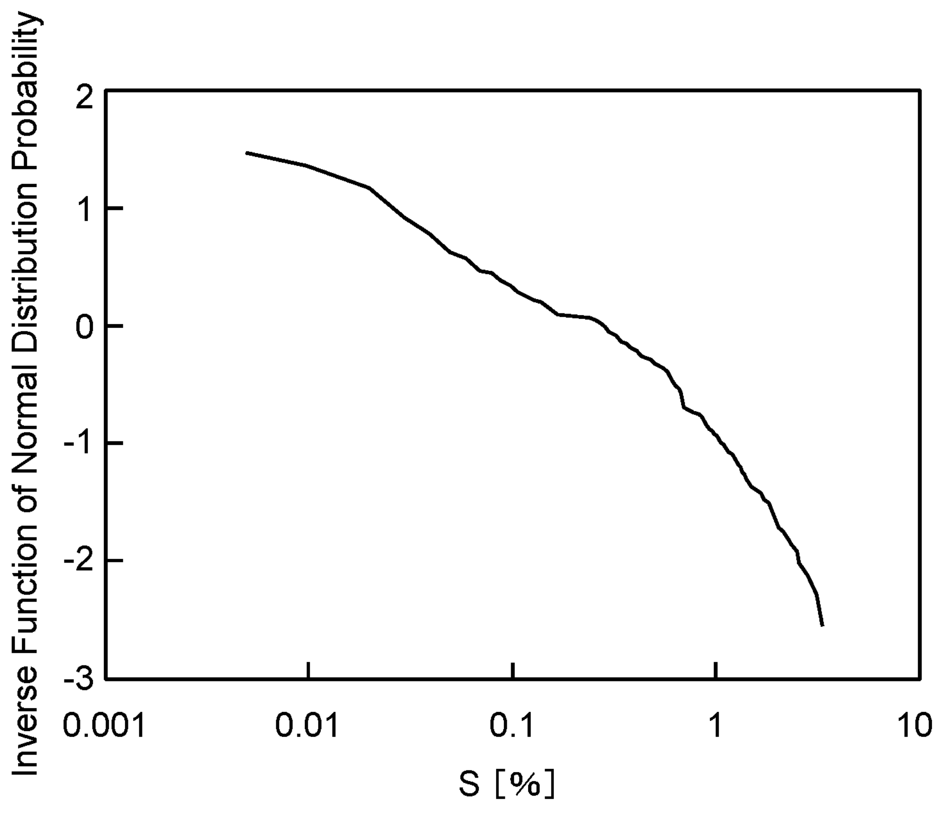


FIG. 6C



160
140
120
100
80
60
40
20
0
Number of Samples [number]
100
80
60
40
20
0
Cumulation [%]
0
0.2
0.4
0.6
0.8
Data Section (common logarithm)

FIG. 7A



Inverse Function of Normal Distribution Probability
2
1
0
-1
-2
-3
0.001
0.01
0.1
1
10
S [%]

FIG. 7B

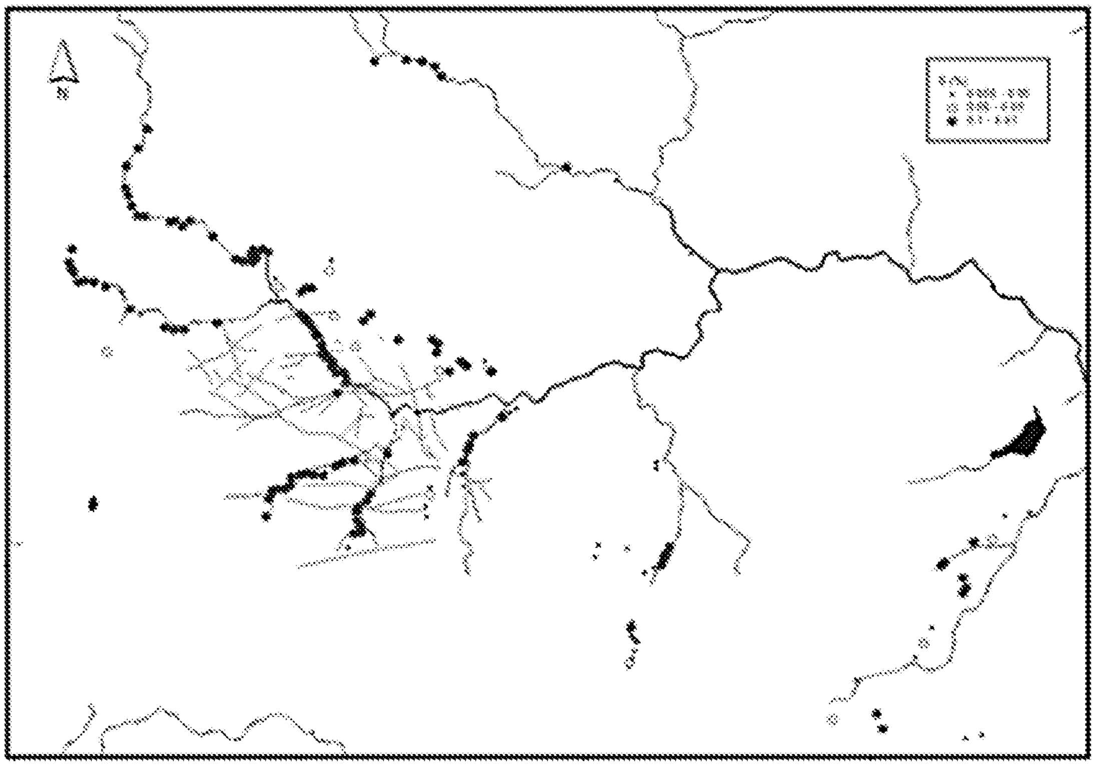


FIG. 7C

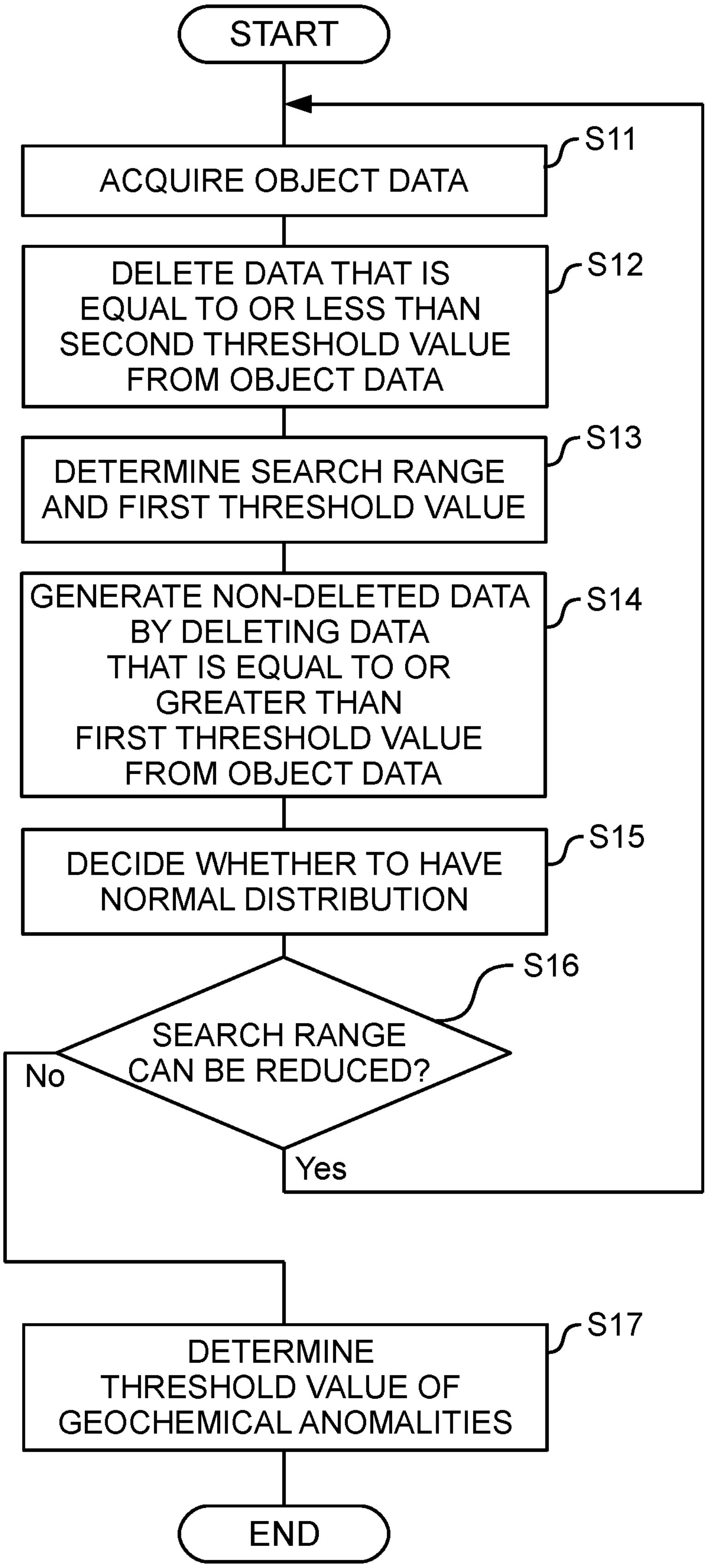

START
ACQUIRE OBJECT DATA
S11
DELETE DATA THAT IS EQUAL TO OR LESS THAN SECOND THRESHOLD VALUE FROM OBJECT DATA
S12
DETERMINE SEARCH RANGE AND FIRST THRESHOLD VALUE
S13
GENERATE NON-DELETED DATA BY DELETING DATA THAT IS EQUAL TO OR GREATER THAN FIRST THRESHOLD VALUE FROM OBJECT DATA
S14
DECIDE WHETHER TO HAVE NORMAL DISTRIBUTION
S15
SEARCH RANGE CAN BE REDUCED?
S16
No
Yes
DETERMINE THRESHOLD VALUE OF GEOCHEMICAL ANOMALITIES
S17
END

FIG. 8

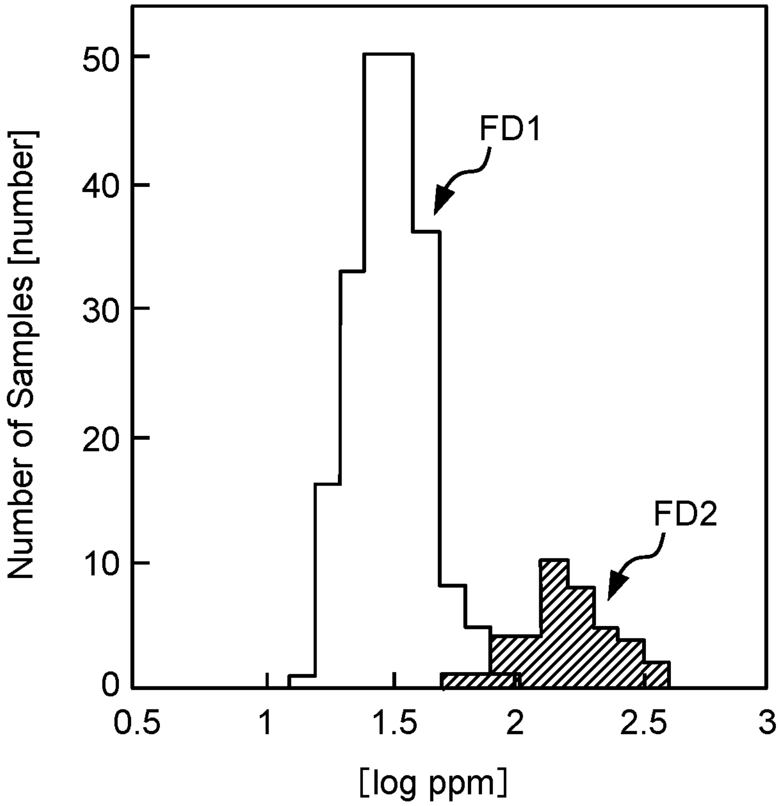

50
40
30
20
10
0
Number of Samples [number]
FD1
FD2
0.5
1
1.5
2
2.5
3
[log ppm]

FIG. 9

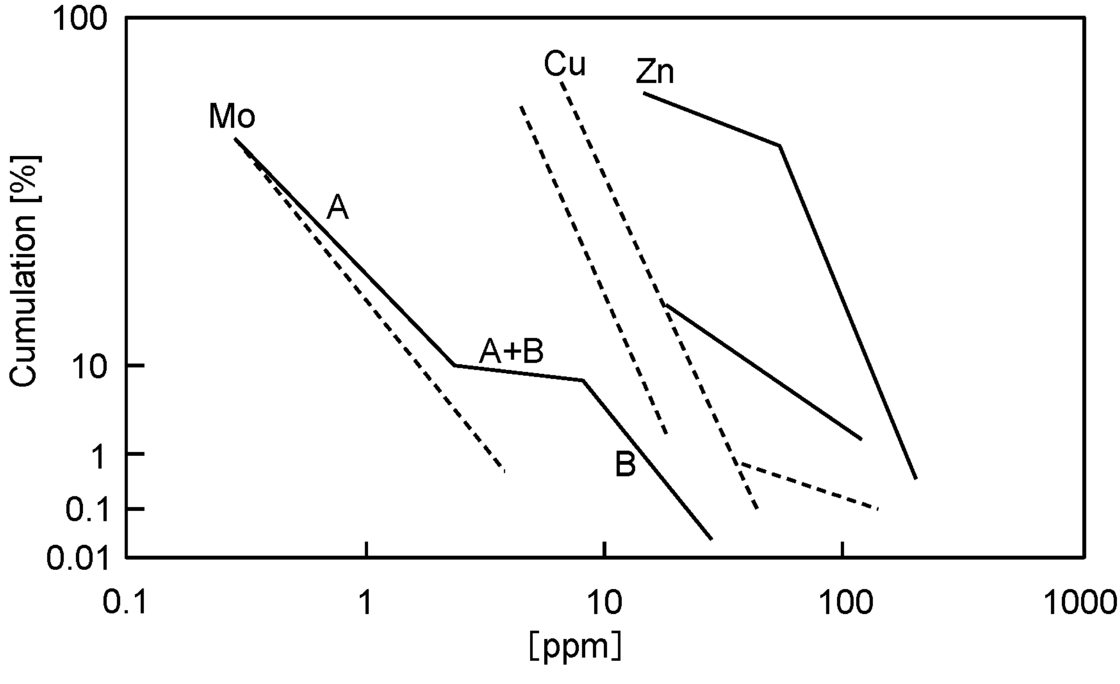

100
10
1
0.1
0.01
Cumulation [%]
Mo
A
A+B
B
Cu
Zn
0.1
1
10
100
1000
[ppm]

FIG. 10

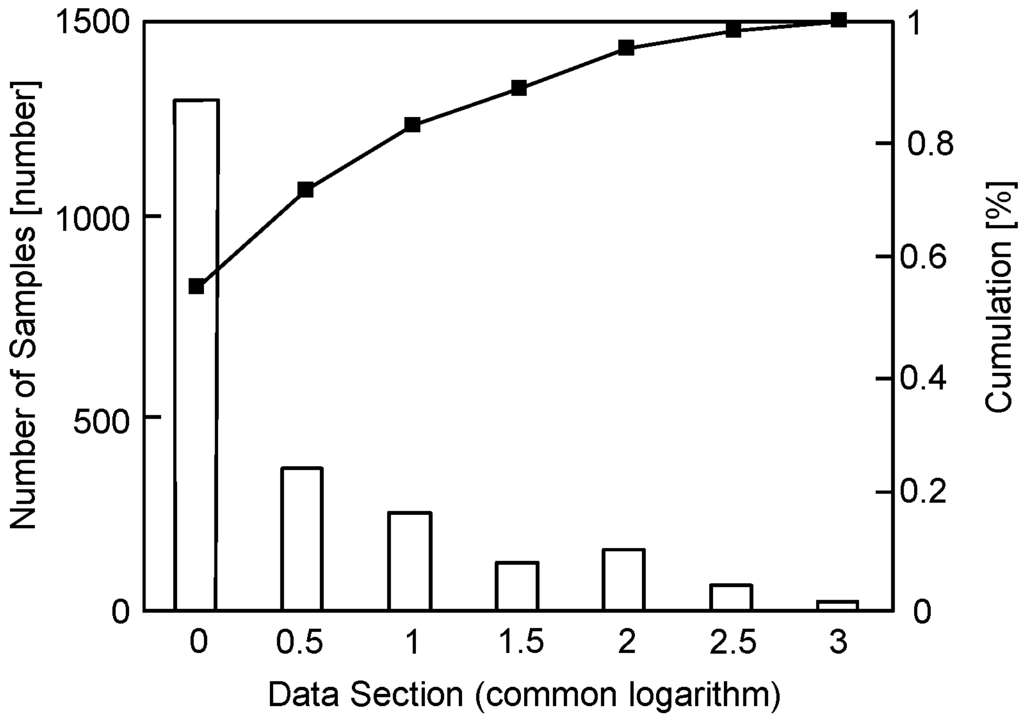


FIG. 11A

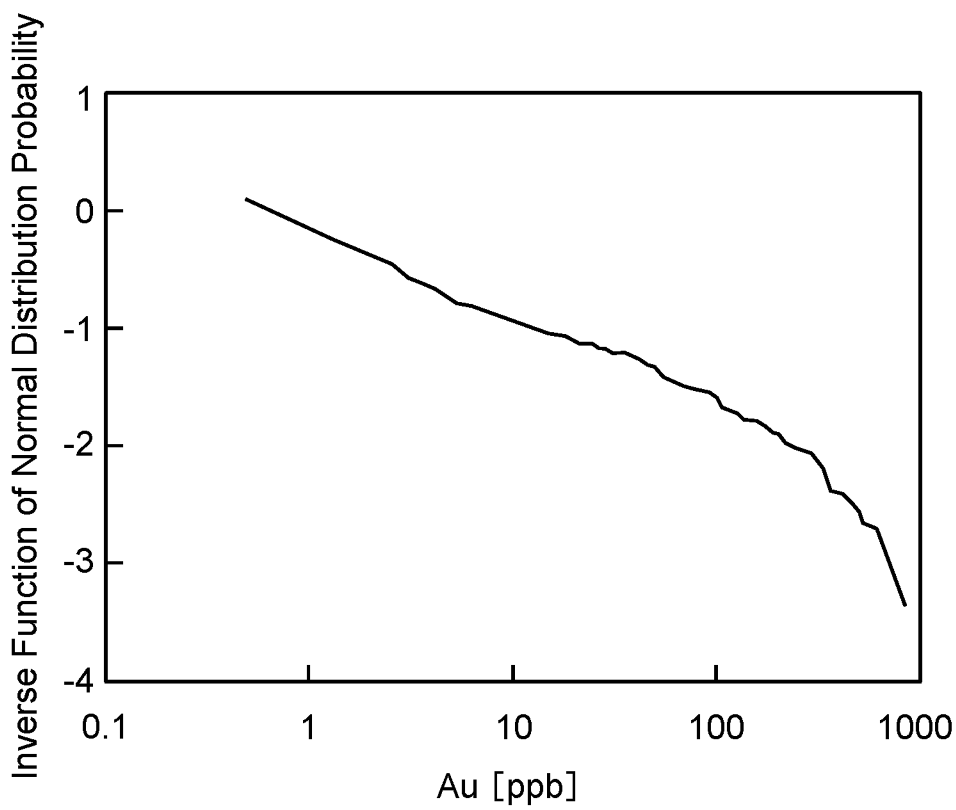


FIG. 11B

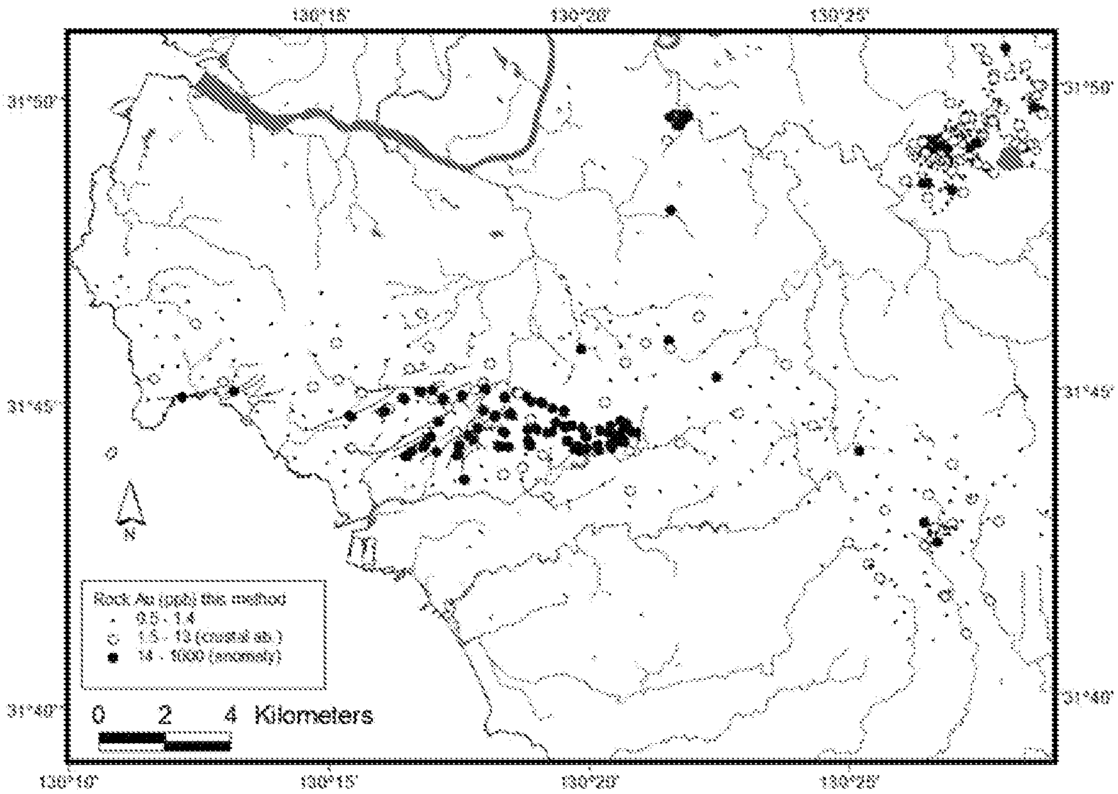


FIG. 11C

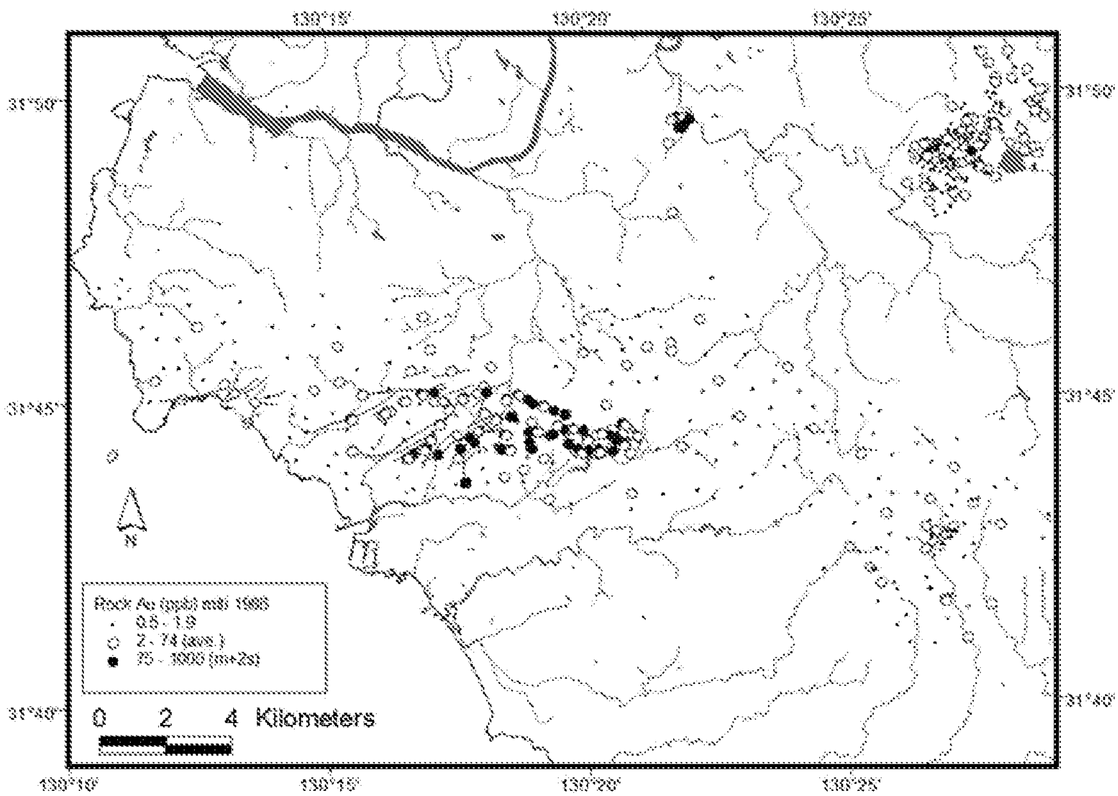


FIG. 11D