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SBGK Szabadalmi Ügyvivői Iroda, Budapest(54) **Eljárás geológiai modellezésre szeizmikus adatokból vonal korrelációval**

Az európai szabadalom ellen, megadásának az Európai Szabadalmi Közlönyben való meghirdetésétől számított kilenc hónapon belül, felszólalást lehet benyújtani az Európai Szabadalmi Hivatalnál. (Európai Szabadalmi Egyezmény 99. cikk(1))

A fordítást a szabadalmas az 1995. évi XXXIII. törvény 84/H. §-a szerint nyújtotta be. A fordítás tartalmi helyességét a Szellemi Tulajdon Nemzeti Hivatala nem vizsgálta.

Method for geologically modeling seismic data by trace correlation**Technical field**

The present invention relates to a method for automatically developing a geological model from seismic data. It has particularly relevant applications in the field of the analysis of seismic data, in particular during the search for new oil fields.

Prior art

Generally, the seismic data represent a subsoil and therefore make it possible to apprehend the geological structure of the zone covered. A seismic signal typically represents the derivative of the acoustic impedance of the layers through which sound pulses which are emitted pass during the acquisition of said seismic data. Therefore, the seismic line is an indirect and degraded representation of the underlying geology. It is indirect because the value of the pixel is not representative of the actual nature of the subsoil at that point, and degraded because the final data are the result of a chain of processing operations (deconvolution, "stacking process"), which introduce artefacts and approximations. Therefore, the reconstruction of the geology based on the seismic line generally requires complex analysis means, which try to identify the geological layers one by one and independently of one another. The existing methods of analysis use as a postulate that one and the same geological layer has similar seismic signatures. Thus, the surfaces are extracted by means of propagators which start from a germ, or by means of classifiers (Kmean) which group the seismic signatures having the same gauge. The main limitation of these techniques results from the basic postulate itself which is never really maintained. In addition, the algorithms used have numerous drawbacks: too strong influence of the seed, drifts of the propagations, invalid surfaces which connect different geological stages, etc.

More recently, global approaches have appeared which aim, in the course of one and the same process, to calculate the entire geological model directly from the seismic data. Among these methods, two large families can be distinguished: those which use the local gradient of the layers and those which use primitives.

In the family of methods using the local gradient of the strata, in particular the document US 6,771,800 of Keskes et al. (2002) is known, which is based on the propagation of 2D lines in

the direction of the gradient. This technique only functions in 2D and does not manage interruptions of continuities of the geology.

The paper by Lomask et al., "Flattening without picking", *Geophysics* vol. 11 no. 4, 2006, pp. 13-20, is known which provides a method for compensating for the gradients by an iterative minimization process. During this process the gradients obtained by calculating the 3D gradient on each seismic point are gradually eliminated, until a flat seismic block without global deformations is obtained, which makes it possible to demonstrate the sedimentation rates by stratigraphic analysis. This technique functions in 3D, but the management of the interruptions of the model necessitates an a priori knowledge of the discontinuities.

In the family of methods using primitives as basic elements of the geological model, these elements are, in a first time, extracted from the seismic image and are then arranged with respect to one another in order to construe the model.

In the method described by Monsen et al. in the document US 2008/0140319, the primitives are geological surfaces of variable sizes obtained automatically by propagation on the extrema of the seismic line. These primitives are then sorted by topological order based on an acyclic graph ("Directed Acyclic Graph", DAG), which represents the superposition relationships between the primitives. The topological order assigned to each surface makes it possible to construe the geological model. This method functions in 3D, it manages the discontinuities of the erosion type, but does not permit automatic management of the faults.

A variant of this approach is proposed by Verney et al. in the document "An Approach of Seismic Interpretation Based on Cognitive Vision", 70th EAGE Conference & Exhibition - Rome, Italy, 9-12 June 2008. In this document, the relationships between mini-surfaces are hierarchized according to their mean vertical distance and the fusion criteria between primitives are based on principles originating from cognitive science. US5056066 and WO03/009002 likewise describe methods for developing geological models.

In the present context of an increasingly competitive and expensive oil market, the search for new fields requires the use of more accurate and quicker automatic analysis tools. The object of the present invention is a method which works at the scale of the seismic point in order to automatically develop a geological model from seismic data, which can

automatically manage the geological discontinuities such as faults, and which permits implementation of multi-scale strategies.

Description of the invention

This object is achieved by a method for developing a computer-implemented geological model from previously collected seismic data, according to claim 1.

Thus, the method according to the invention makes it possible to develop a geological model from an arbitrary sampling grid of the seismic data by exploiting the local similarities of the data. In particular, it is not based on the detection of extrema and the propagation of surfaces from these extrema like the methods in the prior art, but it permits finer modeling of all the data.

The method comprises a step of filling the geological model by propagation of a mini-surface by similarity in the vicinity of each sampling point comprising a link, taking said point as a seed.

However, these mini-surfaces should not be confused with the surfaces propagated as primitives in the methods in the prior art. In fact:

- they are only used to complete the geological model and, in particular, the existing topological relationships between them are not exploited,
- the shape of their contour and their size are essentially determined by the sampling grid,
- because of their very reduced surface, the problems of drifts linked to the propagation algorithms are negligible.

The data of a seismic volume can be sampled in a substantially horizontal plane according to a mesh substantially with any of the following shapes: rectangular, hexagonal, and the traces can have a substantially vertical orientation and can comprise substantially equidistant sampling points.

The determination of the links between sampling points belonging to different traces comprises a step of calculating correlation images,

- each correlation image corresponding to a pair of traces,

- each trace being represented according to a dimension of the correlation image, and
- the value of each point of the image representing the local correlation of the seismic data in the vicinity of the respective two points of each trace.

Furthermore, the method according to the invention can comprise steps of:

- constructing segments in the correlation image by propagation among the points corresponding to correlation values higher than at least a predetermined threshold, said segments corresponding to sets of links or combs of correlations between sampling points of the traces;
- selecting segments of the correlation image, said selection leaving at most only one segment per line and per column of the correlation image, corresponding to one single link per sampling point, and the segments being selected on the basis of the value of the points forming them, and of their length;
- validating the links by analysis of the paths formed by the successions of points linked by said links, a condition for the links to be validated being that, in a seismic volume, the paths are in a loop.

The steps of selecting segments in the correlation image and validating the links are repeated iteratively on the remaining segments in the correlation image, using as a constraint the links validated in the preceding iterations, until there are no longer exploitable segments.

The allocation of a relative geological age to the sampling points is an iterative process performed as long as there remain undated sampling points comprising at least one link, which comprises steps of:

- selecting an undated sampling point comprising at least one link,
- allocating a relative age to this point taking into consideration the already dated points of its trace, so that the age along a trace always varies in the same direction, and
- allocating the same relative age to all the points linked to this point by links.

The method according to the invention can also comprise a step of normalizing the relative ages, the age increment between consecutive relative age points being fixed at a predefined value.

According to another aspect of the method according to the invention, a multi-scale geological model is developed by merging sets of links between sampling points, which sets of connections are obtained with different sampling grids.

The method according to the invention can advantageously be applied in an automated manner, especially:

- to the direct extraction of the deposition surfaces based on iso-values,
- to the horizontalization of the seismic by mapping on a line or a plane the seismic signal corresponding to a geological stage,
- to the analysis of faults, and
- to the analysis of channels.

According to another aspect of the invention, a computer program according to claim 13 is proposed which implements the method according to the invention.

Description of the drawings and embodiments

Further advantages and features of the invention will become clear when reading the detailed description of implementations and embodiments, which are in no way restrictive, and the following drawings:

- Figure 1 illustrates the construction of the correlation image corresponding to two traces of all the seismic data. Figure 1a shows the vertical sampling of the data in seismic traces, whilst Figure 1b shows the construction of the correlation image;
- Figure 2b shows the correlation comb corresponding to a geology referred to as iso-pack with gradient variations such as those shown in Figure 2a;
- Figure 3b shows the correlation comb corresponding to a geology having variations of both gradient and thickness as shown in Figure 3a;
- Figure 4 illustrates the creation of correlation combs between points on either side of a fault having a normal rejection (Figure 4a), or vice versa (Figure 4b).
- Figure 5 illustrates a process of extraction of the segments of a straight line with a high intensity in the correlation image;
- Figure 6 illustrates examples of strategies for sampling the seismic cube;
- Figure 7 illustrates of the validation of the correlation combs by analysis of the paths;
- Figure 8 illustrates the principle of iterative insertion of correlation combs in order to fill the space with the data;

- Figure 9 illustrates an example of application of the algorithm for calculating the reference positions;
- Figure 10 illustrates an example of mini-surfaces obtained in a square sampling grid;
- Figure 11 illustrates the filling of the geological model.

The method according to the invention uses a set of seismic data in order to deduce a geological model therefrom while working at the scale of the seismic points.

The data as described in the preferred embodiment refer to a cube or 3D volume of seismic data. However, the method according to the invention can also be implemented on a two-dimensional set of seismic data, such as cross-sections.

The volume of seismic data can be characterized by 3 axes, i.e. **Inline** and **Xline** axes respectively, substantially parallel to the surface of the ground, and a **TWT** axis oriented in the direction of the increasing depths.

The method according to the invention can be applied to all the data of the seismic volume, but in the general case it is sufficient to be limited to a subset of sampled points in order in particular to limit the calculation time. With reference to Figure 1, a seismic trace, or trace 3, 4, comprises a set of points 5 which are substantially aligned and equidistant, sampled at the depths **t1, t2, t3, etc.** in the direction of the **TWT** axis. The total seismic volume can be sampled by a set of traces arranged in the **Inline-Xline** plane according to a mesh which is, for example, square, hexagonal, even arbitrary, as illustrated in Figure 6.

With reference to Figure 1, a first step of the method according to the invention consists in calculating, for a set of pairs of traces (3, 4) of interest extracted from the seismic data 1, a correlation image $I(X1, X2)$, **X1** and **X2** being the respective positions of the seismic traces 3, 4. This correlation image 2 represents all the correlation coefficients calculated between the **N1** points proceeding from **X1** and the **N2** points proceeding from **X2**. In this image of dimensions (**N1*N2**) pixels, if **X1** is on the ordinate and **X2** on the abscissa, the value of the point **P(i, j)** located in column **i** and on line **j** is the correlation coefficient **Cf(i, j)** calculated between the **i**-th point of the trace **X2** and the **j**-th point of the trace **X1**.

The correlation coefficients **Cf(i, j)** can be calculated, for example, based on the correlation of a mini-trace **Vi** of the size **S**, centered around a point **X2(i)** and a seismic mini-trace **Vj** of

the size S centered around a point $X1(j)$. The mode of calculating the coefficients $Cf(i, j)$ can also, and non-restrictively, comprise any type of calculation of the distance or differences between the two vectors V_i and V_j .

In Figure 1, for example, the value of the point 8 of the correlation image 2 is the result of the calculation of the correlation between the mini-trace 6 around the point 5 having the position t_3 in the trace X_2 with the mini-trace around the point having the position t_1 of the trace X_1 . According to a non-restrictive convention, the mode of calculating the value of the points of the correlation image 2 is defined such that this value increases with the similarity of the vectors V_i and V_j .

Each point of the correlation image $I(X_1, X_2)$ such as 8 therefore corresponds to a connection, for example 7, between a point of the trace X_1 and a point of the trace X_2 . A point that has a high value in $I(X_1, X_2)$ represents a link with a high probability between X_1 and X_2 . Thus, the correlation image shows all the high-probability links between two seismic traces. With reference to Figure 2, when the high probability points are contiguous in the correlation image 2, their relevance increases, because they are no longer isolated within the geological context, but form a consistent set 10 which connects two geological stages. These contiguous sets correspond to correlation combs 11 in the space of the data 1, said combs being defined by the sets E of points $P(i, j)$ of the image $I(X_1, X_2)$ such that no point $P(i, j)$ of E has neither the same abscissa nor the same ordinate as one of the other points of E . This property expresses the fact that, in a given comb, a seismic point is linked only to one single link.

In the case of a completely laminar geology with a zero gradient, the traces X_1 and X_2 are similar and the segment with the highest correlation is located on the diagonal of the image 2, with a leading coefficient substantially equal to 1. The resulting comb then comprises horizontal links.

In the case of a geology referred to as iso-pack with gradient variations as illustrated in Figure 2, the two traces X_1 and X_2 have similar signatures, but are offset. The segment with the highest correlation 10 is then parallel to the diagonal, with a leading coefficient substantially equal to 1, and the distance 12 between the diagonal and the segment represents the value of the rejection, i.e. of the offset along the **TWT** axis, between X_1 and X_2 .

Likewise, in the most general case where the geology has variations both in gradient and in thickness, as illustrated in Figure 3, the segment with the highest correlation 10 has a direction coefficient different from 1, because the rejection varies along the comb 11.

Advantageously, the method according to the invention is not sensitive to the presence of faults, in contrast to the propagation methods used in the prior art in order to obtain seismic surfaces and primitives. By using the correlation comb method, relationships or links 7 between the points can be established on either side of the fault 20, irrespective of the value and the (normal or reverse) direction of the reject, as illustrated in Figure 4.

The combs 11 can be detected automatically by extracting segments of a straight line 10 with a high intensity of the correlation image $I(X1, X2)$. This detection can advantageously be performed for example based on an algorithm comprising the following steps, illustrated in Figures 5a to 5f, respectively:

- classifying the points of the image $I(X1, X2)$ into three families: **INVALID**, **VALID** and **UNCERTAIN** depending on their correlation value (Figure 5a);
- using all the points classified as **VALID** as a seed for propagating the segments. The candidate points for the propagations are only the points classified as **VALID** and **UNCERTAIN** (Figure 5b);
- searching all the points of $I(X1, X2)$ which have the maximum value on a line or on a column. These points are marked as **MAXP** (Figure 5c);
- eliminating the segments which do not contain any point marked as **MAXP** (Figure 5d);
- eliminating the segments of which the length is smaller than the median length of the segments obtained in the preceding step (Figure 5e);
- presenting each segment starting from the longest to the shortest one. Each segment presented eliminates all the segments which have a point on the same line or on the same column of the correlation image (Figure 5f). Thus, the longest segment 10 corresponding to the longest comb 11 is obtained, while ensuring that the seismic points of the comb 11 are only associated with one single link.

In order to detect the combs 11 on all the data of the seismic block, it is necessary to select positions of the pairs of traces **X1** and **X2** on the basis of which a correlation image is

calculated. These traces can be positioned anywhere in the seismic block. If the machine capacities permit it, all the traces of the seismic cube and therefore all the points can be used. However, as a general rule a sampling of the seismic cube is necessary.

Advantageously it is possible to opt for a regular sampling strategy in which one trace out of N possible traces is taken and all the images $I(\mathbf{X}_i, \mathbf{X}_j)$ are calculated such that the positions \mathbf{X}_i and \mathbf{X}_j are distant from N , for example, according to a substantially square or hexagonal mesh (Figures 6a and 6b). A random strategy can also be implemented, in which all the pairs $(\mathbf{X}_i, \mathbf{X}_j)$ are drawn at random (Figure 6c). It is also possible advantageously to combine several strategies, the only aim being to obtain a sufficient number of combs 11 so that the crux of the seismic block is characterized.

This flexibility of use gives the method according to the invention a considerable advantage, because it permits easy implementation of the multi-scale or multi-resolution strategies by combining, for example, distant combs of N samples with distant combs of $2 \cdot N$ samples. The use of the combs with several scales or levels of resolution permits better processing, for example, of large-scale geological factors such as fault or erosion zones.

The method according to the invention can comprise a step of validation of the links, based on an analysis of the paths formed by the successions of seismic points linked to one another by these links. Indeed, in so far as a link, by definition, connects points which are located on one and the same geological surface, by covering a path link by link it is normally necessary to remain on the same surface. If a path does not form a closed loop, it is rejected because there is no certainty with regards to its relevance. If a path comprises two different points belonging to one and the same trace 31, as illustrated in Figure 7b, it is also not validated, because it passes through different geological stages along its path. On the other hand, if the path returns to exactly the same starting point 30 without overlapping (Figure 7a), it is validated because the probability that it is on the same surface is high. When a path is validated, all the links of which it is composed are also validated. Likewise, when a certain number of links are validated in a comb, the whole comb is validated, because it is considered that the combs are indissociable and relevant units.

Although this criterion for validation of the links is challenging, it makes it possible to fill the seismic space with combs having a geological consistency. With this technique, a valid link

can pass over geological surfaces which exhibit strong variations of gradient and have faults passing through them.

An iterative process can advantageously be implemented in the method according to the invention in order to fill the studied seismic volume to the maximum, so as to build a final model which is as complete as possible with a maximum of links. Each iteration of this process comprises a detection, then a validation of a set of combs, as described above. Each new iteration is constrained by the preceding iterations. As the seismic space is gradually filled, the number of possibilities for inserting new combs decreases.

Let it be assumed that there is a pair $(X1, X2)$ of two traces. If in the course of the first iteration a comb has been validated between $X1$ and $X2$, this latter will serve as a constraint for the following iteration because it limits the range of available solutions for a second comb. This principle is illustrated in Figure 8. In this figure, the segments corresponding to three relevant combs are present in the correlation image. The most obvious segment 40 corresponding to the comb 43 is validated during the first iteration. For the second iteration, the entire gray portion of the image is no longer available in accordance with the principle according to which there can be only one link per pair of points. Consequently, the segment 42, of which an excessively large proportion of the links overlaps in the gray zone, is eliminated from the list of candidates. Only the segment 41 corresponding to the comb 44 remains available.

The first valid combs are positioned on the seismic line of good quality which has the best correlations. These combs will then serve as a constraint for the second waves of combs, during the second iteration, which will use the available space with a seismic line of less good quality. Thus, the geological constraint provided by the existing links will be gradually enriched, so as to compensate for the gradual loss of quality of the seismic line which remains unprocessed. Advantageously, the space is gradually covered, even in the zones having a low signal/noise ratio. A condition for stopping the iterative process can be, for example, the absence of new detected combs.

Thus, the method according to the invention permits filling of the space with the data of correlation combs connecting the points of the pairs of traces (X_i, X_j) . Let it be assumed that E_p is all the seismic points located on all the pairs (X_i, Y_j) . Advantageously, it is possible to assign to each point P of E_p a reference position which is calculated with the validated links

and which represents the position of P in the geological context. This reference position makes it possible to establish a hierarchy of points P , from the youngest to the oldest one. This calculation can be carried out for example on the basis of the following algorithm:

$ValRef(P)$ = reference value for a point P

Step is the increment of the position values, for example **Step** = 1

(Initialization)

For all the points P , do

P = UNMARKED

insert P into **GlobalStack**.

$ValRef(P)$ = 0.

End Do

(Calculation of the positions)

Extract **GlobalStack** in **nextP**

As long as **nextP** exists, Do

P = **nextP**

nextP = UNKNOWN

insert P into **LocalStack1** and into **LocalStack2**

minValRef = UNDEFINED and **maxValRef** = UNDEFINED

As Long As **LocalStack1** is not empty Do

Pop **LocalStack1** in K

If **nextP** = UNKNOWN Then

Search for **PAbove** the first UNMARKED point located above K

Search for **PBelow** the first UNMARKED point located below K

If **PAbove** exists, then **nextP** = **PAbove**

If **PBelow** exists, then **nextP** = **PBelow**

End If

Search for **PAboveMark** the first MARKED point located above K

Search for **PBelowMark** the first MARKED point located below K

If **PAboveMark** exists and if $ValRef(PAbove) > minValRef$, then **minValRef** = $ValRef(PAbove)$

If **PBelowMark** exists and if $ValRef(PBelow) < maxValRef$ then **maxValRef** = $ValRef(PBelow)$

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For all the points V which are UNMARKED linked to K by a link Do
    V = MARKED
    insert v into LocalStack1 and into LocalStack2
End For
End As Long As
If minValRef = UNDEFINED and maxValRef = UNDEFINED, then
    minValRef = 0 and maxValRef = 0
If minValRef=UNDEFINED and maxValRef different from UNDEFINED
then minValRef = maxValRef- 2*step
If maxValRef = UNDEFINED and minValRef different from
UNDEFINED then maxValRef = minValRef + 2*step
As Long As LocalStack2 is not empty, Do
    Extract LocalStack2 in K
    ValRef(K) = (maxValRef + minValRef)/2.
End As Long As
If nextP = UNKNOWN, do
    As long as nextP = UNKNOWN do
        Extract GlobalStack in P
        If P = UNMARKED, then nextP = P
    End As Long As
End If
End As Long As

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This algorithm is quick, since each point P is visited only one single time. Figure 9 shows the process for calculating the reference positions in a case where the thickness varies from right to left. In this example, the increment pitch is equal to 10. The figure shows respectively (a) all the links in the case of a variation of the thickness, (b) the initialization of the positions on the first trace with an increment of 10 (c, d, e and f), the calculation of the relative positions on each one of the virgin links, with respect to the lower and upper links.

The reference positions form an arbitrary time scale in which the points of the seismic line are positioned with respect to one another. Advantageously, it is possible, by passing through this time scale from the most recent to the oldest, to normalize the relative age of

the points so that the variation of positions between two consecutive points on the time scale is constant.

At this stage, only part of the points of the seismic line has a reference position: this is the set E_p of the points which comprise a valid link. The number of points depends on the number of correlation combs detected, which in turn depends upon the sampling carried out for positioning the pairs of traces (X_1 , X_2). In order to fill all of the seismic space with reference positions, it is advantageously possible to construct small surfaces of which the shape and the topology depend upon the seismic signal and the type of sampling which has been chosen. Each point referenced in E_p can serve as a seed G for calculating a mini-surface based on a conventional propagation algorithm by similarity of seismic mini-trace. The spatial extent of this mini-surface is advantageously limited to the "Voronoi cell" associated with the seed G . The definition of a Voronoi cell is as follows: Let it be assumed that E is a set of points and S is a subset of E (S is a sampling of E). If P is a point of S , the Voronoi cell associated with the point P is the set of points present in E which are closer to P than to all the other points of the subset S .

In the case of the method according to the invention, the set E can represent all the points of the surface of the seismic block and S can represent the positions of the traces X_i , used for calculating the correlation images.

Advantageously, the reference position associated with G is assigned to all the points of a mini-surface propagated from a seed G . This technique makes it possible to fill all of the space while maintaining the variations of the local gradient. It should be noted that, contrary to the prior art methods, the method is not limited to the extrema of the seismic line, but a mini-surface is created for each point comprising a valid link. Likewise, in comparison with the methods according to the prior art which use propagated surfaces as primitives, the mini-surfaces calculated in the method according to the invention have very particular characteristics:

- the shape of their contour and their size is essentially determined by the sampling grid,
- because of their very reduced surface, the problems of drifts linked to the propagations are negligible,
- they are used only to complete the model, and in particular the topological relationships existing between them are not exploited.

Figure 10 shows an example of mini-surfaces obtained in a square sampling grid.

The filling of the geological model is shown in Figure 11, (a): seismic image, (b): all the validated links, (c): mini-surfaces propagated from the points linked to the validated links, (d): reference positions obtained for each point of the image (a).

According to advantageous characteristics of the method according to the invention,

- the models obtained are very precise, because the reference primitives are the seismic points. In the methods according to the prior art which use surfaces as primitives, the real modeling is possible only on the extrema, the rest of the information being obtained by vertical interpolation between the extrema. In the method according to the invention, no interpolation is required, which permits less approximation and therefore more precision
- in the approaches in the prior art based on primitives, a surface is indivisible, there is a set of indissociable points which always have the same value in the geological model. This rigidity eliminates any possibility of controlling the model within one and the same surface. The quality of the model therefore depends upon the quality of extraction of the primitives. In the method according to the invention the model can be constrained at any point of the seismic space by simply adding a link. The model retains all its flexibility and the control can be performed without limitation;
- it may be interesting to combine several analysis scales in the interpretation of the seismic data. For example, a local analysis focused on the small variations of the seismic signal can be mixed with a more global analysis relating to the large events such as the high rejections of faults or the variations in thickness. With the methods of modeling in the prior art the use of several scales within one and the same calculation is very difficult to implement, in contrast to the method according to the invention in which it is sufficient to vary the distances between the traces on which the correlation images are calculated;
- the correlation combs used in the method according to the invention can find links between the geological strata located on either side of the faults irrespective of the amplitude and the direction of the rejection. Thus, the method according to the invention permits better management of the geological discontinuities than the other methods in the prior art depending upon a local analysis such as the propagation or the local calculation of the gradient.

The method according to the invention can advantageously be applied to automatic analyses of geological parameters such as:

- the direct extraction of the deposition surfaces based on iso-values. The method according to the invention permits a significant time gain, because it makes it possible to omit the manual extraction process by pointer, which is extremely long and tedious. The surfaces obtained are a very rich source of information, because they constitute the fundamental and first element for numerous systems and methods for analyzing the geology;

- the horizontalization of the seismic line, which consists in mapping the seismic signal corresponding to a geological stage on a line or on a horizontal plane. By thus processing several successive stages, a so-called straightened seismic line can be reconstructed in which all the reliefs of the geological deposits are smoothed. The method according to the invention is advantageously implemented for this type of applications, very often used in particular in the search for hydrocarbons, because the relief of each surface is then known with, additionally, a very good precision and a high reliability;

- the analysis of the faults which are slippages of the geological strata along a fracturing surface. This fracturing generates an interruption of continuity of the geological depositions which, in the seismic field, results in a disturbance of the signal. Thus, in the resulting image of geological modeling the presence of a fault will result in sudden variations of the topological values which occur along surfaces. These two criteria make it possible to extract faults in the form of vectored surfaces and also to map the amplitude of the rejection along the faults;

the analysis of the channels, which are old terrestrial or submarine river beds filled with sediments. In oil exploration, these channels constitute privileged targets, because they have all the characteristics of the hydrocarbon traps. The phenomena of digging and filling flow beds are quick on the geological scale and result, in the image of geological modeling obtained by applying the method according to the invention, in sudden variations in thickness of the geological stages in the form of lenses. These morphological features are selective enough to allow automatic three-dimensional mapping of the channels.

Of course, the invention is not limited to the examples which have been described and numerous modifications can be made thereto without departing from the scope of the invention.



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ELJÁRÁS GEOLÓGIAI MODELLEZÉSRE SZEIZMIKUS ADATOKBÓL VONAL KORRELÁCIÓVAL

Szabadalmi igénypontok

1. Eljárás számítógéppel megvalósított geológiai modell kidolgozására előzetesen gyűjtött szeizmikus adatokból, amely tartalmazza a következő lépéseket:

- a szeizmikus adatok (1) mintavételezése legalább egy készlet szeizmikus vonal (3, 4) mentén, amelyek mindegyike növekvő mélységű mintavételezési pontokból (5) áll,
- a szeizmikus adatok (6) közötti hasonlóság analízise a különböző szeizmikus vonalakhoz (3, 4) tartozó mintavételezési pontok (5) körül,
- a kapcsolatok (7) meghatározása a különböző vonalakhoz tartozó mintavételezési pontok (5) hasonlóság analíziséből, amely kapcsolatok összekötik az azonos geológiai felületen lévő pontokat, amely meghatározás korrelációs képek (2) egy számításának lépését is tartalmazza,
- minden korrelációs kép egy pár vonalhoz (3, 4) tartozik,
- minden vonal, mint a korrelációs képek (2) egy dimenziója van megjelenítve, és
- a korrelációs képek (2) minden pontjának értéke a szeizmikus adatok (6) korrelációját reprezentálja az egyes vonalak (3, 4) két vonatkozó pontja (5) közelében;

ahol amely tartalmazza a következő lépést:

- az említett geológiai modell olyan kialakítása, hogy minden egyes mintavételezési ponthoz (5) egy relatív geológiai kort rendelünk, amely legalább a következőkből van számítva:

- (i) más mintavételezési pontok relatív geológiai korából, amelyek az említett mintavételezési ponthoz (5) kapcsolattal (7) vannak kötve, és
- (ii) más mintavételezési pontok relatív geológiai korából, amelyek szomszédosak a vonallal (4), beleértve az említett mintavételezési pontot (5) is,

a relatív geológiai kor hozzárendelése az egyes mintavételezési pontokhoz (5) egy iteratív folyamat, amelyet mindaddig hajtunk végre, amíg legalább egyetlen kapcsolattal (7) rendelkező dátumozatlan mintavételezési pontok (5) maradnak, és amely tartalmazza a következő lépéseket:

- egy legalább egy kapcsolattal (7) rendelkező dátumozatlan mintavételezési pont (5) kiválasztása,
- egy relatív kor hozzárendelése ezen mintavételezési ponthoz (5), figyelembe véve vonalának (4) már dátumozott pontjait úgy, hogy a kor egy vonal mentén mindig ugyanabban az irányban változik, és
- ugyanazon relatív kor hozzárendelése minden mintavételezési ponthoz amely ezen ponthoz van kapcsolattal (7) kapcsolva, és tartalmazza azt a lépést, hogy kitöltésre kerül a geológiai modell egy mini-felületi hasonlóság alapján, amely kiterjesztésre kerül a kapcsolattal (7) rendelkező mintavételezési pont (5) környezetében, a pontot (5) tekintve magnak.

2. Az 1. igénypont szerinti eljárás, ahol:

- a szeizmikus mennyiségi adatok (1) mintavételezése lényegében horizontális síkon történik, nevezetesen egy földfelszínnel párhuzamos tengelyeket (Inline és Xline) tartalmazó síkban; ahol a hálózat a következők bármelyike szerinti alakú: négyszögletes, hatszögletes, sőt egyéb alakzatú; és
- a vonalaknak (3, 4) lényegében vertikális irányítottsága van, nevezetesen egy növekvő mélységi irányú tengely (TWT) mentén, és lényegében illesztett, ekvidisztáns mintavételezési pontokat (5) tartalmaz, nevezetesen mivel mélységben (t_1, t_2, t_3, \dots) vannak mintavételezve, az említett tengely (TWT) irányában.

3. Az 1. igénypont szerinti eljárás, amely tartalmaz egy lépést szegmensek (10) létrehozására a korrelációs képből (2), kiterjesztéssel olyan pontok (8) között, amelyeknél a korrelációs érték egy előre meghatározottnál nagyobb, amely szegmensek (10) megfelelnek a vonalak (3, 4) mintavételezési pontjainak (5) kapcsolatainak vagy kapcsolatcsoportjainak (11).

4. A 3. igénypont szerinti eljárás, amely tartalmaz egy lépést a korrelációs kép (2) szegmenseinek (10) kiválasztására,

- amely kiválasztás legtöbbször eredményez a korrelációs kép (2) soraiban és oszlopaiban egyetlen szegmenseket (10), amely mintavételezési pontonként (5) egyetlen kapcsolatnak (7) felel meg, és
- a szegmensek (10) az azokat alkotó pontok (8) értékei és hosszúságuk alapján kerülnek kiválasztásra.

5. A 4. igénypont szerinti eljárás, amely tartalmaz egy lépést a kapcsolatok (7) validálására, a pontok (5) kapcsolatokkal (7) összekapcsolt sorozata nyomvonalának (30, 31) analízise által, a feltétel, miszerint a kapcsolatok (7) validálásra kerülnek egy szeizmikus mennyiségben az, hogy a nyomvonalak hurkot (30) alkotnak.

6. Az 5. igénypont szerinti eljárás, amelyben a korrelációs kép (2) szegmenseinek (10) kiválasztása és a kapcsolatok (7) validálása lépések iteratív módon ismétlésre kerülnek a korrelációs kép (2) fennmaradó szegmenseiben (41, 42), az előző iterációkban validált kapcsolatok (40) alapul vételével, mindaddig, amíg nem marad felhasználható szegmens.

7. Az 1. igénypont szerinti eljárás, amely tartalmaz egy lépést a relatív korok normalizálására, a pontok (5) közötti kor növekmény az egymás utáni relatív koroknál egy előre meghatározott értékben van rögzítve.

8. Az előző igénypontok bármelyike szerinti eljárás, amelyben egy több-skálájú geológiai modell van kidolgozva a mintavételezési pontok közötti kapcsolatok készleteinek egyesítésével, amely kapcsolat készletek különböző mintavételi rácsok mentén lettek előállítva.

9. Az előző igénypontok bármelyike szerinti eljárás, lerakódási felületek közvetlen kinyerésére alkalmazva, iso-értékek alapján.

10. Az 1-8. igénypontok bármelyike szerinti eljárás, szeizmikus horizontálásra alkalmazva, a geológiai helyszínek megfelelő szeizmikus jelek vonal vagy felület menti

letapogatásával.

11. Az 1-8. igénypontok bármelyike szerinti eljárás, hiba analízisre alkalmazva.
12. Az 1-8. igénypontok bármelyike szerinti eljárás, csatorna analízisre alkalmazva.
13. Egy számítógép program az előző igénypontok bármelyike szerinti eljárás lépéseinek megvalósítására.

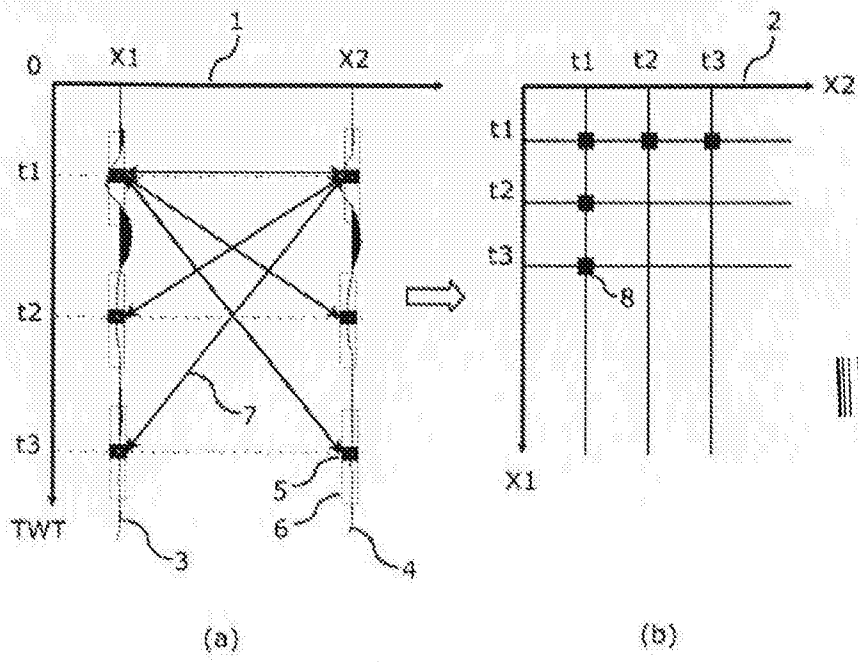


Figure 1

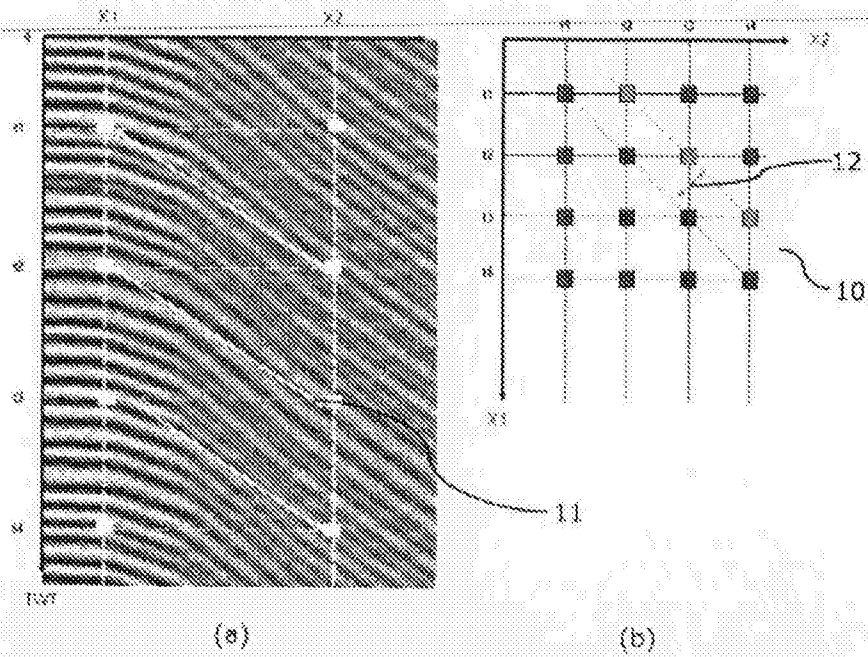


Figure 2

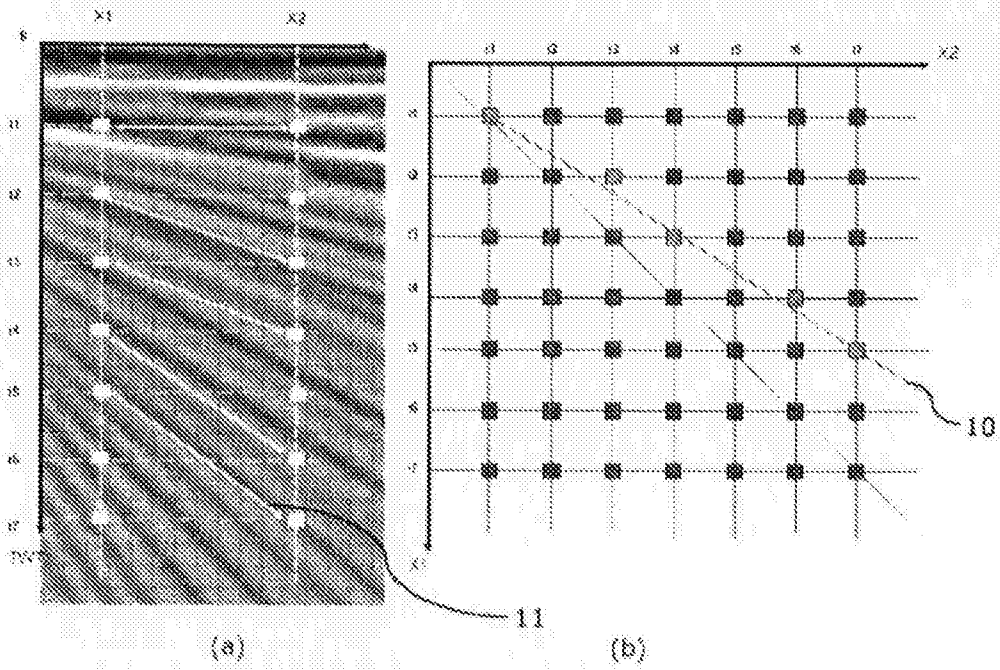


Figure 3

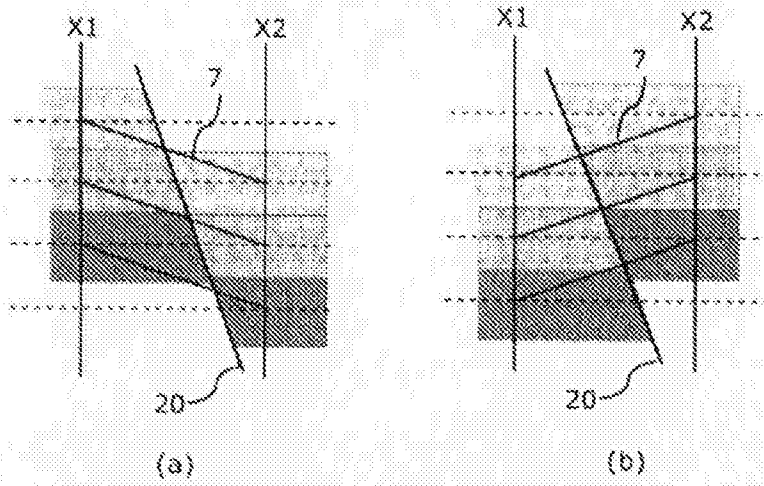


Figure 4

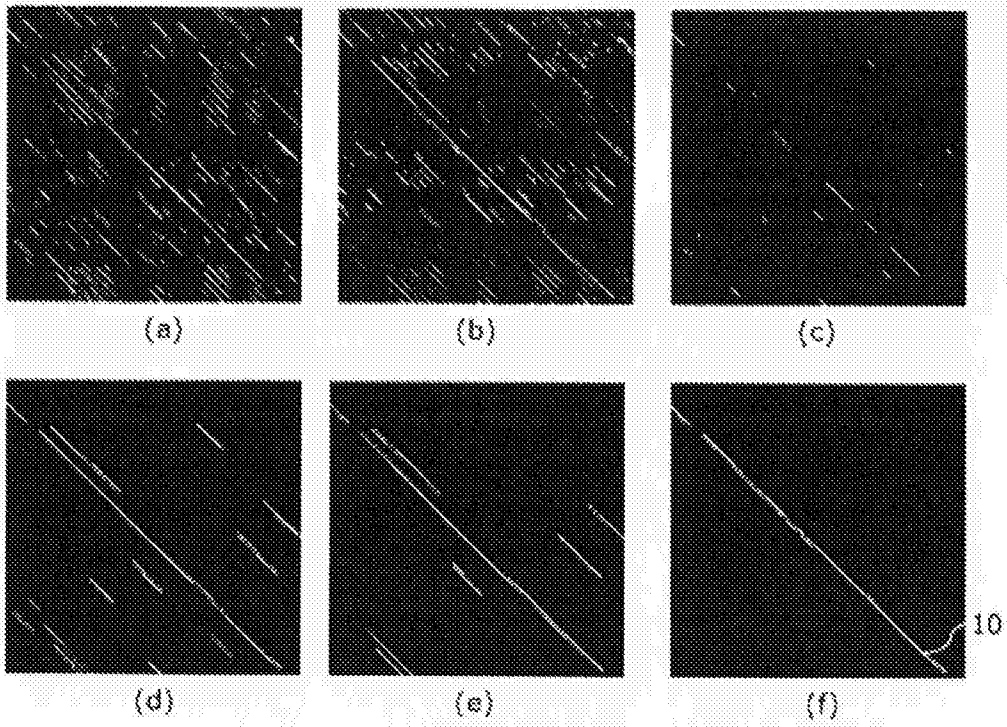


Figure 5

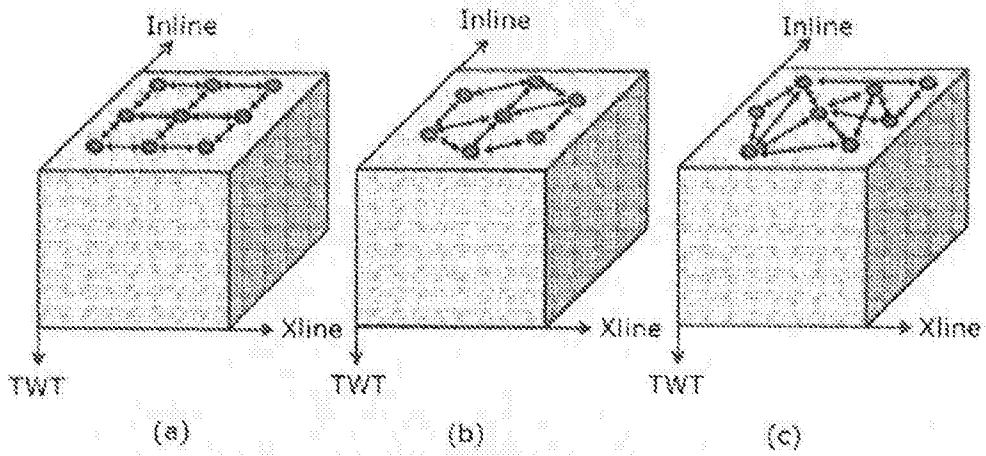


Figure 6

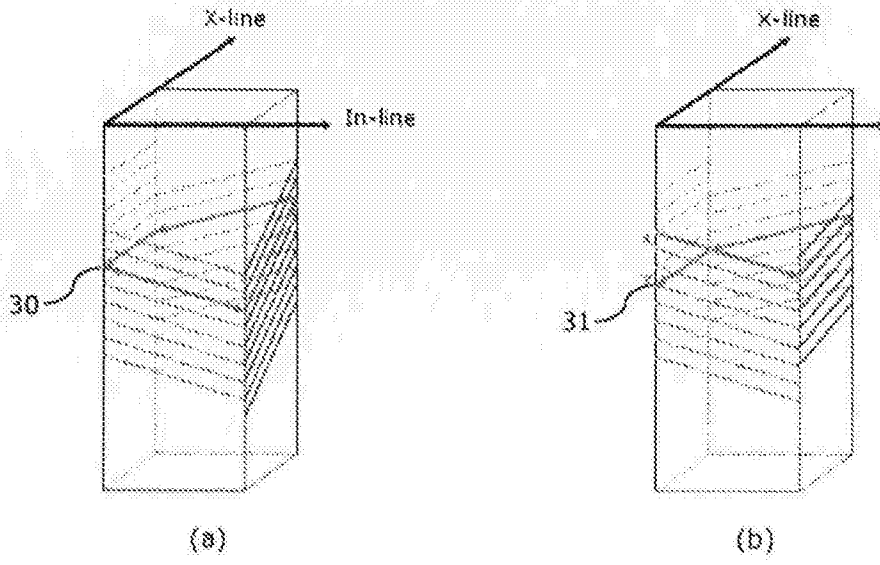


Figure 7

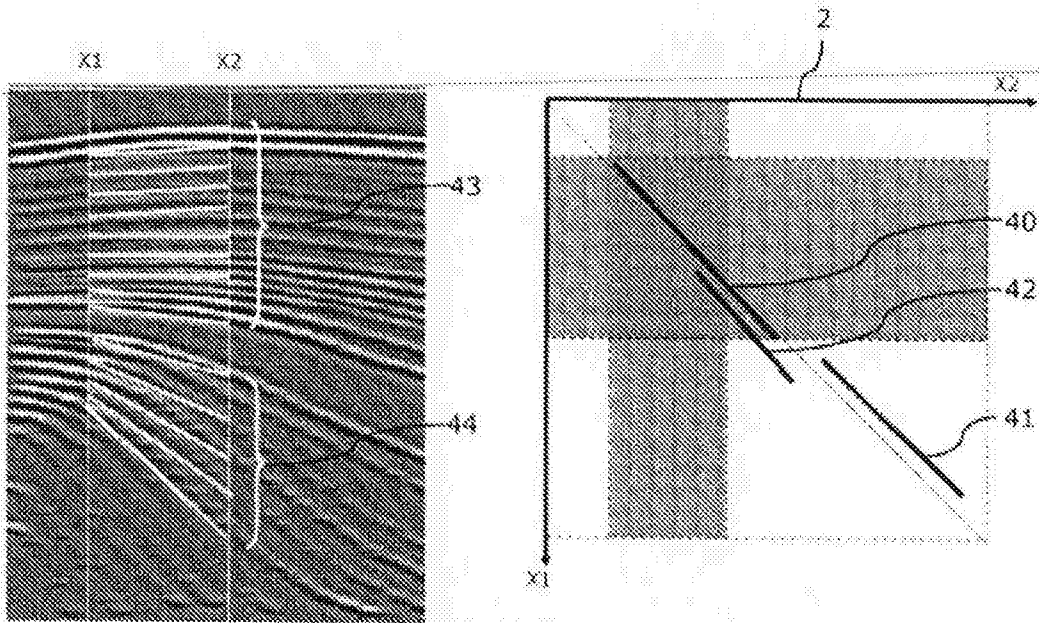


Figure 8

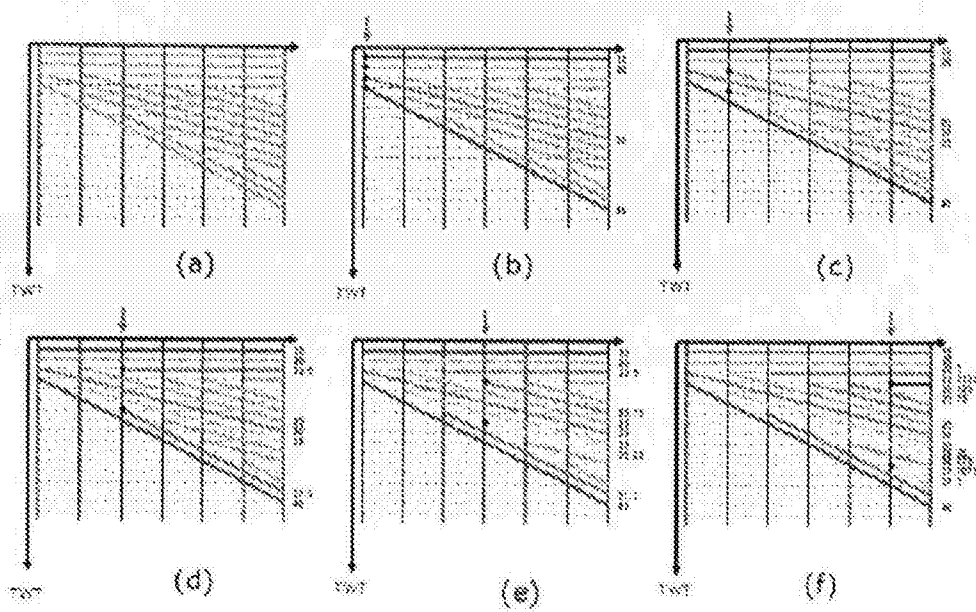


Figure 9

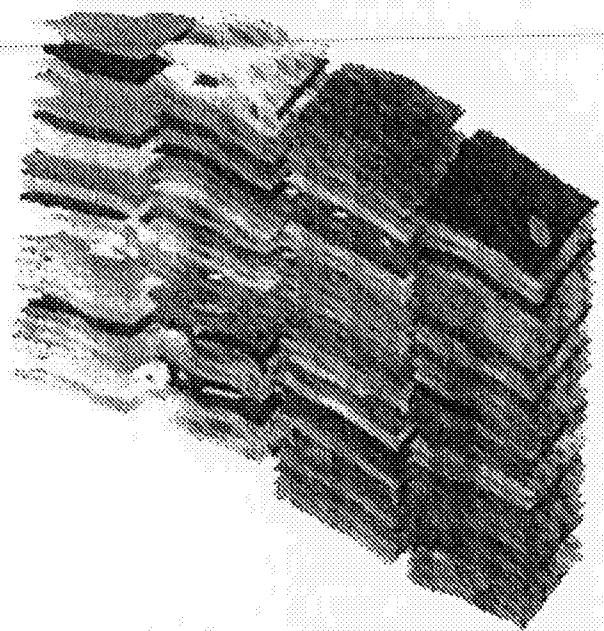
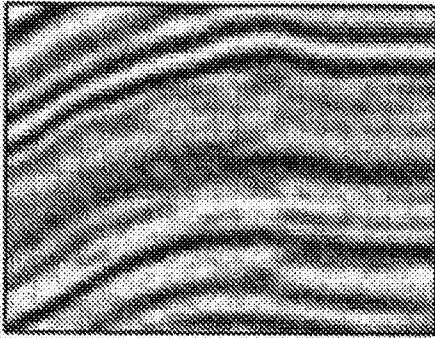
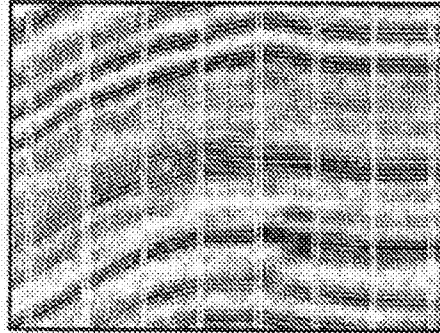


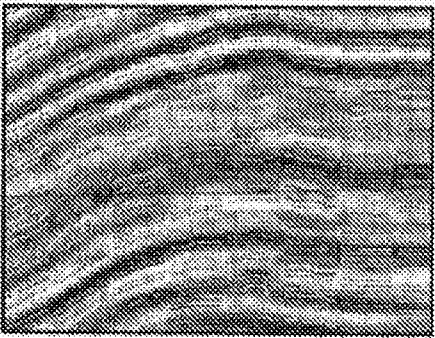
Figure 10



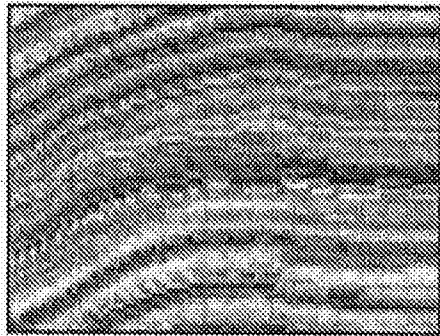
(a)



(b)



(c)



(d)

Figure 11