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Inversion Method of SP Anomaly by Stochastic Parameter Regulation

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The great leader Kim Jong Il said:

"It is also important to introduce the up-to-date successes of physical prospecting."

What is important in inversion to find out the state of placement of anomalous body buried under the earth by interpreting geophysical prospecting data is to overcome the ambiguity of solution. For this, we should use physical properties and comprehensive geophysical prospecting data of the research region and several other quantitative interpreting methods. [2]

This paper newly proposed stochastic parameter regulation (SPR) method that stably converges into correct solution without relation to original values of model, and verified its reliability through experiment of model calculation.

1. Principle of SPR Method

Geophysical inversion can largely be divided into two classes, one of which is stochastic statistical inversion (SSI) method (Monte-Carlo method, Simulated Annealing method, Genetic Algorithm method, Stochastic Hill-climbing method etc.) and the other is non-stochastic statistical inversion (NSSI) method (Gradient method, Conjugated Gradient method, Regulation method, Marquadt method etc.).

The biggest advantage of SSI method is that it does not fall into local extremum (false solution) and its disadvantage is that it has a lot of calculating quantities to decide global extremum. The NSSI method has quick convergence speed but it also has the disadvantage of not being able to determine correctly the true solution as it easily falls into local extremum.

The advantage of SPR method, as it combines the advantages of stochastic hill-climbing method and parameter regulation method in the above-mentioned two classes, is that it can quickly determine solution without falling into local extremum.

The algorithm of SPR method is as follows:

① An original model is randomly generated on the basis of prior information.

② A new model is made by using similar Chauchy distribution depending on temperature.

$$\boldsymbol{P}_i' = \boldsymbol{P}_i + Q(B_i - A_i) \tag{1}$$

$$Q = T \cdot \mathrm{sign}(\theta - 0.5)[(1 + 1/T)^{|2\theta-1|} - 1] \tag{2}$$

where, $\boldsymbol{P}_i$ and $\boldsymbol{P}_i'$ are i^{th} parameter of an old model and a new model (i.e. before and after fluctuation) respectively, θ is the random number distributed uniformly between [0, 1], T is the annealing temperature, A_i and B_i are lower and upper bound of variation of i^{th} parameter respectively, sign is the signal function. Hence $\boldsymbol{P}_i' \in [A_i, B_i]$.

The judgment for the new model is made by the difference $\Delta S = S_{\text{new}} - S_{\text{old}}$ of objective functions (S_{old}, S_{new}) before and after fluctuation. If $\Delta S < 0$, the new model is accepted and if $\Delta S > 0$, it is abandoned and a new model is made again.

If fluctuation is over, the annealing temperature is changed. The annealing temperature is decreased by the mode of hyperbolic line descent.

$$T = T_0 \beta^k \tag{3}$$

where, T_0 is the original temperature, β is a number smaller than 1 as a damping factor, and k is the number of repetition.

It will have a long calculating time if T_0 value is too large and the correct solution cannot be determined because new models are selected only in neighborhood of original model if it is too small. Therefore, T_0 value must be determined through experiment.

If the annealing temperature reaches the converting temperature of inversion (CTI) T_c, the algorithm moves to step ⑥ and if it doesn't, it moves to step ② and the algorithm process is repeated.

The results of solution by stochastic hill-climbing method were selected as original values for model calculating and the inversion is carried out by parameter regulation method.

2. Experiment of Model Calculation

2.1. Determination of CTI (T_c)

The CTI is the limited temperature, which passes from stochastic hill-climbing method to parameter regulation method. It has to be selected so that the whole calculating time of inversion could be decreased to a maximum while the result of solution of stochastic hill-climbing method is placed within convergence radius of the parameter regulation method.

The model used in experiment is a polarization body of self-potential formed thick dike of infinite strike length. We considered convergence properties with different model parameters and T_c values (Table 1). Here, the whole number of data points is 51 points, distance between points is 1 (RU=Related Unit), original temperature is 10^4 ℃, number of fluctuation is 40 times.

Table1. Suitable determination of T_c

No	x_0 (RU)	h(RU)	$\alpha/(^\circ)$	K/mV	l(RU)	B(RU)	T_c/℃
1	25	1	50	500	10	5	0.01
2	25	1	50	50	20	2	100
3	25	5	50	500	20	2	1000
4	25	5	90	500	4	2	0.01
5	25	5	90	500	1	20	0.001
6	25	10	50	500	10	2	1000
7	25	10	50	300	10	2	0.1

x_0 : Horizontal location of body, h : Top depth of body, α : Polarization angle,
K : Electromotive force of polarization, l: Depthless elongation length, b : Half thickness of body

As shown in Table 1, the T_c value is the limited value allowing convergence into true value in regulation method, and therefore the smaller model size and the shallower model depth, the smaller its value, and the larger model size and the deeper model depth, the bigger its value. Hence suitable value of T_c is 0.001℃.

2) Noise effect

Since the information of geophysical prospecting measured in field includes noise components by several factors, we have verified the stability of the present method using the following data with noise:

$$f_{\text{obs}} = f_{\text{mod}}[1+(-1)^{\text{Int(Rnd}\cdot 10)}\text{Rnd}\cdot\eta/100] \tag{4}$$

where, f_{obs} and f_{mod} are potential fields with and without noise respectively, Rnd is a random number, η is noise content(%).

When η values are 1, 5, 10%, the result of interpretation equals that of Table 2.

Table 2. Verification of noise effect

Model		1%		5%		10%	
Parameter	True value	Estimated value	Relative error /%	Estimated value	Relative error /%	Estimated value	Relative error /%
x_0 (RU)	25	25.012	0.048	25.058	0.232	25.123	0.492
h(RU)	5	5.084	1.68	5.39	7.8	5.731	14.62
$\alpha/(^\circ)$	50	50.227	0.454	51.1	2.2	52.176	4.352
K/mV	500	500.45	0.091	492.84	1.432	472.38	5.524
l(RU)	20	19.701	1.492	18.536	7.32	17.06	14.7
b(RU)	4	4.051	1.275	4.343	8.575	4.874	21.85

As shown in Table 2, the horizontal location of model has the smallest noise effect among estimated parameters, and when noise is 10%, relative error of estimated value is about 0.5%. The thickness of dike has the largest noise effect, and when noise is 10%, relative error of estimated value is about 22%. When noise is 10%, the mean relative error of model parameters is 10.26% similar to noise size. Therefore, in interpretation of field data, smoothing and filtering should be done well.

3. Interpreting example of measured data

The interpreted result of prospecting data for ultra-anthracite gained in “ㅎ”region, Ryongyon County, South Hwanghae Province by our proposed method is equal to that in the Fig.

We have selected the length of survey line as 230m and the distance between measured points as 5m. On the basis of prior information on this area, we have regarded the form of anomalous body that caused SP anomaly as horizontal cylinder of infinite strike.

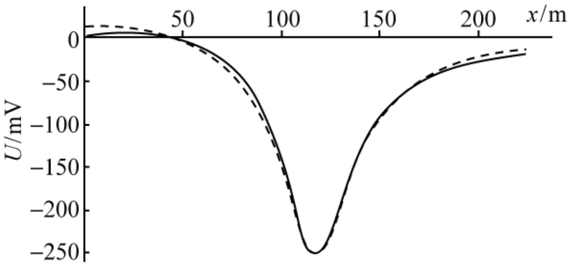

Fig. Survey curve (dotted line) and analysis curve (solid line)

As shown in the Figure, the measured curve corresponds with analysis curve comparatively. The horizontal location of anomalous body is 114.6m, vertical location is 21.5m and polarization angle is 102.3°.

Conclusion

The SPR method can be used in processing measured data since it has strong global searching power for solution without recourse to any selected original value of anomalous body and quick speed of convergence.

References

[1] 师学明; 工程地球物理学报, 4, 3, 165, 2007.
[2] 劉士毅 等; 物探与物探, 34, 6, 691, 2010.