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重力近区地形改正精度探讨

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摘 要: 在大比例尺重力勘探工作中, 近区、中区地形改正误差对重力总精度影响较大。在实际工作中, 近区域地形改正一般采用实测或用地形图读图计算; 中区地形改正一般采用地形图读图计算,《大比例尺重力勘查规范》只考虑地形图高程精度对重力总精度的影响, 忽略了地形图平面坐标精度对重力总精度影响。这里从锥形、扇形基本地形改正公式推导出发, 探讨不同比例尺, 不同高程, 平面精度对重力总精度的影响, 并提出了不同地形改正精度对地形图比例尺及高程, 平面精度要求建议。

关键词: 地形改正; 高程精度; 平面精度; 比例尺
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1 近区地形改正公式的推导

见图 1直角坐标系, 以测点 A 作为坐标原点, X、Y 轴在水平面内, Z 轴垂直向下。设地面中质量单元 dm 坐标为 (ξ, η, ζ)。根据万有引力定理, dm 对 A 点所产生的引力垂直分量为:

$$dg = G\frac{dm}{\rho^2}\cdot\cos\theta \tag{1}$$

其中 G 为万有引力常数 $(6.67\times10^{-8}\ cm^3/(g\cdot s^2))$; ρ 为测点 A 到质量单元 dm 的距离; θ 为 ρ 与 Z 轴的夹角。

对式(1)的积分, 就是周围高于或低于 A 点的全部地形影响。

$$\Delta g = G\int\frac{dm}{\rho^2}\cdot\cos\theta \tag{2}$$

又由图 1可知, $\rho^2=\xi^2+\eta^2+\zeta^2$, $\cos\theta=\zeta/\rho$, $dm=\sigma d\xi d\eta d\zeta$ 则:

$$\Delta g = G\sigma\iiint\frac{\zeta}{(\xi^2+\eta^2+\zeta^2)^{\frac{3}{2}}}d\xi\cdot d\eta\cdot d\zeta \tag{3}$$

式(3)是地形改正的基本公式, 在实际工作中, 只能采用近似的方法计算地形改正值。

扇形公式: 引用柱坐标系 (R, α, ζ), 则有:

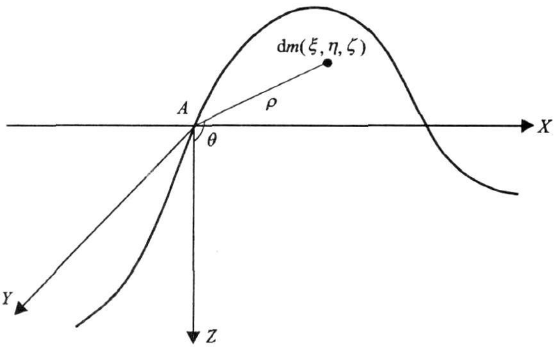

图 1 重力测点示意图

Fig 1 Gravity measurement points diagram

$$d\xi\cdot d\eta\cdot d\zeta = R\,d\alpha\cdot dR\cdot d\zeta$$

$$\Delta g = G\sigma\iiint\frac{R\zeta}{(R^2+\zeta^2)^{3/2}}d\alpha\cdot dR\cdot d\zeta \tag{4}$$

对图 2(见下页)所示的扇形, 被半径 R、α_i 和 α_{i+1} 所包围的扇形:

$$\Delta g = G\sigma\int_0^h\int_{R_i}^{R_{i+1}}\int_{\alpha_i}^{\alpha_{i+1}}\frac{R\zeta}{(R^2+\zeta^2)^{3/2}}d\alpha\cdot dR\cdot d\zeta \tag{5}$$

其中 h 为扇形柱体相对测点的平均高差, 对式(5)积分得

$$\Delta g = G\sigma(\alpha_{i+1}-\alpha_i)(R_{i+1}-R_i+\sqrt{R_i^2+h^2}-\sqrt{R_{i+1}^2+h^2}) \tag{6}$$

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若令 $\alpha_{i+1}-\alpha_i=\dfrac{2\pi}{n}$, 即将整个圆环分成等份, 则有:

$$\Delta g=\frac{2\pi G\sigma}{n}\left(R_{i+1}-R_i+\sqrt{R_i^2+h^2}-\sqrt{R_{i+1}^2+h^2}\right)\qquad(7)$$

锥形体如图 3所示, 锥形体的高度 h 是 R 与地形倾角 θ 的函数, $h=R\cdot \mathrm{tg}\theta$。

$$\Delta g=G\sigma\int_0^{R\mathrm{tg}\theta}\int_0^{R}\int_{\alpha_i}^{\alpha_{i+1}}\frac{R\zeta}{(R^2+\zeta^2)^{\frac{3}{2}}}\mathrm{d}\alpha\cdot \mathrm{d}R\cdot d\zeta\qquad(8)$$

对 ζ 积分得:

$$\Delta g=G\sigma\int_0^{R}\int_{\alpha_i}^{\alpha_{i+1}}\frac{1}{(1+\mathrm{tg}^2\theta)^{1/2}}\mathrm{d}\alpha\cdot \mathrm{d}R\qquad(9)$$

$$\Delta g=G\sigma(\alpha_{i+1}-\alpha_i)(1-\cos\theta)\qquad(10)$$

若令 $\alpha_{i+1}-\alpha_i=\dfrac{2\pi}{n}$, 则有:

$$\Delta g=\frac{2\pi G\sigma R}{n}(1-\cos\theta)\qquad(11)$$

$$\Delta g=\frac{2\pi G\sigma R}{n}\left(1-\cos\left(\mathrm{tg}^{-1}\frac{h}{R}\right)\right)\qquad(12)$$

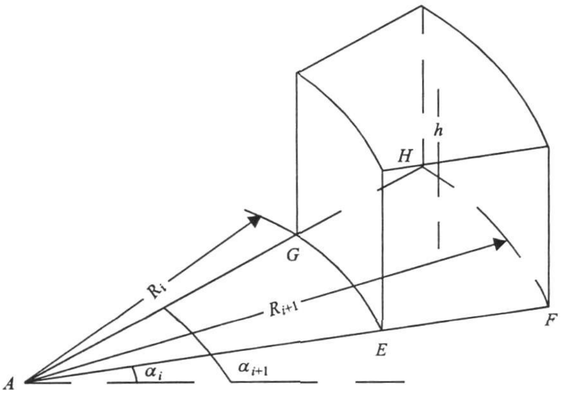

图 2　扇形地形改正计算模型图

Fig. 2　Sector map terrain correction calculation model diagram

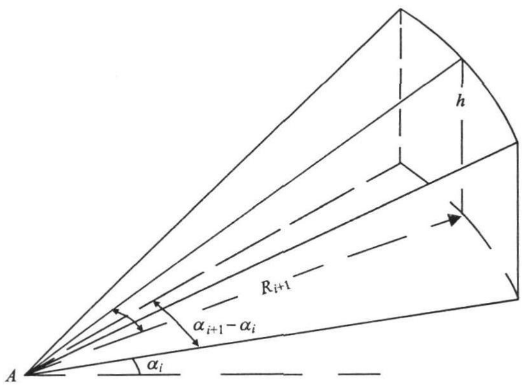

图 3　锥形地形改正计算模型图

Fig. 3　Cone terrain correction calculation model diagram

从公式(6)看出, 同样的高差, 距测点越远, 地改值越小, 地形影响越小。因此从地改的总精度来考虑, 近区地改应尽可能精准一些。

2　误差分析

从式(6)、式(11)看出, 影响地形改正的因素有密度 σ、地改半径(R_i, R_{i+1})及高差 h。为估算误差, 以 σ、R、h 为变量进行微分得:

$$\mathrm{d}\Delta g_{锥}=\frac{2\pi G}{n}\left\{R\left[1-\cos\left(\mathrm{tg}^{-1}\frac{h}{R}\right)\right]\mathrm{d}\sigma+\sigma\left[\sin\left(\mathrm{tg}^{-1}\frac{h}{R}\right)\cdot\frac{1}{1+\left(\frac{h}{R}\right)^2}\right]\mathrm{d}h+\sigma\left[1-\cos\left(\mathrm{tg}^{-1}\frac{h}{R}\right)-\sin\left(\mathrm{tg}^{-1}\frac{h}{R}\right)\cdot\frac{1}{1+\left(\frac{h}{R}\right)^2}\cdot\frac{h}{R}\right]\mathrm{d}R\right\}\qquad(13)$$

$$\mathrm{d}\Delta g_{扇}=\frac{2\pi G}{n}\left\{\left(R_{i+1}-R_i+\sqrt{R_i^2+h^2}-\sqrt{R_{i+1}^2+h^2}\right)\mathrm{d}\sigma+h\sigma\left(\frac{1}{\sqrt{R_i^2+h^2}}-\frac{1}{\sqrt{R_{i+1}^2+h^2}}\right)\mathrm{d}h+\sigma\left[\left(\frac{R_i}{\sqrt{R_i^2+h^2}}-1\right)\mathrm{d}R_i+\left(1-\frac{R_{i+1}}{\sqrt{R_{i+1}^2+h^2}}\right)\mathrm{d}R_{i+1}\right]\right\}\qquad(14)$$

将微分换成中误差则:

$$m^2\mathrm{d}\Delta g_{锥}=\left(\frac{2\pi G}{n}\right)^2\left\{R^2\left[1-\cos\left(\mathrm{tg}^{-1}\frac{h}{R}\right)\right]^2(\mathrm{d}\sigma)^2+\sigma^2\left[\sin\left(\mathrm{tg}^{-1}\frac{h}{R}\right)\cdot\frac{1}{1+\left(\frac{h}{R}\right)^2}\right]^2(\mathrm{d}h)^2+\sigma^2\left[1-\cos\left(\mathrm{tg}^{-1}\frac{h}{R}\right)-\sin\left(\mathrm{tg}^{-1}\frac{h}{R}\right)\cdot\frac{1}{1+\left(\frac{h}{R}\right)^2}\cdot\frac{h}{R}\right]^2(\mathrm{d}R)^2\right\}\qquad(15)$$

$$m^2\mathrm{d}\Delta g_{扇}=\left(\frac{2\pi G}{n}\right)^2\left\{\left(R_{i+1}-R_i+\sqrt{R_i^2+h^2}-\sqrt{R_{i+1}^2+h^2}\right)^2(\mathrm{d}\sigma)^2+(h\sigma)^2\cdot\left(\frac{1}{\sqrt{R_i^2+h^2}}-\frac{1}{\sqrt{R_{i+1}^2+h^2}}\right)^2(\mathrm{d}h)^2+(\sigma)^2\left[\left(\frac{R_i}{\sqrt{R_{i+1}^2+h^2}}-1\right)^2(\mathrm{d}R_i)^2+\right.$$

$$\left(1-\frac{R_{i+1}}{\sqrt{R_{i+1}^{2}+h^{2}}}\right)^{2}(dR_{i+1})^{2}\Big]\Big\} \qquad (16)$$

式中 $d\sigma$ 为密度误差; dh 为高程误差; dR 为地改半径误差。

下面根据不同比例尺地形图(其等高距见表1),不同地形条件的高程误差及平面位置误差,估算地形改正误差(忽略密度误差对地形改正的影响),不同环的平均高差以地形倾角大约10°为准,换算出高差 h。高程误差有二种:①当地形为丘陵时,高程误差为该比例尺地形图等高距的1/2;②当地形为山地时,高程精度为该比例尺地形图等高距的2/3。平面精度(不含读图误差)为图上0.8 mm,根据公式(15)、式(16),计算出近区、中区地形改正采用不同比例尺地形图可能达到的精度,结果见表2、表3,统计结果见下页表4、表5。

后面的表6、表7是不同比例尺规范中对地形改正的技术要求。

从公式(15)、公式(16)及表2、表3(见下页)可看出,重力地形改正精度与密度、高程及点位有关,这里忽略密度误差,只讨论高程及点位因素。

表1 地形图基本等高距划分表

Tab.1 Basic contour topographic maps from the division table

比例尺	基本等高距(m)				
	平地	丘陵	山地	高山	备注
	< 2°	2°~6°	6°~25°	> 25°	地面倾角
1:500	0.5	1.0	1.0	1.0	
1:1000	0.5	1.0	1.0	2.0	
1:2000	1.0	1.0	2.0	2.0	
1:5000	1.0	2.5	5.0	5.0	
1:10000	1.0	2.5	5.0	10.0	
1:25000	5.0	5.0	10.0	10.0	
1:50000	10.0	10.0	20.0	20.0	

表2 估算地形改正误差计算表(丘陵)

Tab.2 Error computing table of terrain correction (Hills) with estimation

区域	地改范围(m)	高差(m)	地形图比例尺	高程精度(m)	(高差中误差)^2 $(10^{-8}\,m/s^2)^2$	平面精度(m)	(点位中误差)^2 $(10^{-8}\,m/s^2)^2$	地改误差 $(10^{-8}\,m/s^2)$	备注
近区	0~10	2	1:500	±0.5	1.7392	±0.3	0.0059	3.7364	锥形公式计算
			1:1000	±0.7	3.4089	±0.6	0.0321	5.2401	
			1:2000	±0.7	3.4089	±1.2	0.0943	5.2939	
	10~20	5	1:500	±0.5	2.049	±0.3	0.2119	4.2529	扇形公式计算
			1:1000	±0.7	2.049	±0.6	0.8478	4.8139	
			1:2000	±0.7	4.016	±1.2	3.3911	7.6978	
中区	20-40	8	1:1000	±0.7	2.945	±0.6	0.3868	5.1628	扇形公式计算
			1:2000	±0.7	2.945	±1.2	1.5474	5.9949	
			1:5000	±1.5	13.523	±2.5	6.7161	12.7245	
			1:10000	±1.5	13.523	±5.0	26.8645	17.9750	
	40~100	15	1:1000	±0.7	3.942	±0.6	0.2941	5.8214	扇形公式计算
			1:2000	±0.7	3.942	±1.2	1.1766	6.3991	
			1:5000	±1.5	18.1009	±2.5	5.1066	13.6257	
			1:10000	±1.5	18.1009	±5.0	20.4265	17.5562	
	100~200	30	1:1000	±0.7	1.8524	±0.6	0.1339	3.9862	扇形公式计算
			1:2000	±0.7	1.8524	±1.2	0.5356	4.3707	
			1:5000	±1.5	8.5057	±2.5	2.3245	9.3082	
			1:10000	±1.5	8.5057	±5.0	9.2979	11.9344	
远区	200~400	50	1:5000	±1.5	6.1813	±2.5	1.1630	7.6651	扇形公式计算
			1:10000	±1.5	6.1813	±5.0	4.6518	9.3094	
			1:25000	±2.5	17.1703	±12.5	29.0738	19.2342	
			1:50000	±5.0	68.6811	±25.0	116.2952	38.4683	
	400~1000	80	1:5000	±1.5	5.9611	±2.5	0.4735	7.1747	扇形公式计算
			1:10000	±1.5	5.9611	±5.0	1.8940	7.9272	
			1:25000	±2.5	16.5586	±12.5	11.8378	15.0722	
			1:50000	±5.0	66.2343	±25.0	47.3510	30.1444	
	1000~2000	150	1:5000	±1.5	2.3813	±2.5	0.1593	4.5082	扇形公式计算
			1:10000	±1.5	2.3813	±5.0	0.6370	4.9139	
			1:25000	±2.5	6.6146	±12.5	3.9815	9.2070	
			1:50000	±5.0	26.4585	±25.0	15.9260	18.4140	

注:平面位置中误差不超过地形图0.8 mm;高程中误差为基本等高距的2/3。

表 3 估算地形改正误差 ($10^{-8}m/s^2$)计算表(山地)

Tab. 3 Error computing table of terrain correction (Mountain) with estimation

区域	地改范围(m)	高差(m)	地形图比例尺	高程误差(m)	(高差中误差)^2 ($10^{-8}m/s^2$)^2	平面误差(m)	(点位中误差)^2 ($10^{-8}m/s^2$)^2	地改误差($10^{-8}m/s^2$)	备注
近区	0~10	2	1: 500	±0 7	3. 4089	±0 4	0. 0105	3. 4193	锥形公式计算
			1: 1000	±1 0	6. 9569	±0 8	0. 0419	6. 9988	
			1: 2000	±1 5	15. 653	±1. 6	0. 1676	15. 8206	
	10~20	5	1: 500	±0 7	4. 0160	±0 4	0. 3768	5. 9281	扇形公式计算
			1: 1000	±1 0	8. 1959	±0 8	1. 5071	8. 8105	
			1: 2000	±1 5	18. 4408	±1. 6	6. 0286	13. 9912	
中区	20~40	8	1: 1000	±1 0	6. 0102	±0 8	0. 6877	7. 3201	扇形公式计算
			1: 2000	±1 5	13. 523	±1. 6	2. 7509	11. 4102	
			1: 5000	±3 0	54. 0921	±3 75	15 1113	23. 5293	
			1: 10000	±3 0	73. 6254	±7. 5	60 4452	32. 7500	
	40~100	15	1: 1000	±1 0	8. 0448	±0 8	0. 5229	8. 279	扇形公式计算
			1: 2000	±1 5	18. 1009	±1. 6	2. 0917	12. 7099	
			1: 5000	±3 0	72. 4035	±3 75	11 4899	25. 9065	
			1: 10000	±3 0	72. 4035	±7. 5	45 9597	30. 7718	
	100~200	30	1: 1000	±1 0	3. 7803	±0 8	0 238	5. 6698	扇形公式计算
			1: 2000	±1 5	8. 5057	±1. 6	0. 9521	8. 6984	
			1: 5000	±3 0	34. 023	±3 75	5 23	17. 7207	
			1: 10000	±3 0	34. 023	±7. 5	20 9202	20. 9653	
远区	200~400	50	1: 5000	±3 0	24. 7252	±3 75	2. 6166	14. 7897	扇形公式计算
			1: 10000	±3 0	24. 7252	±7. 5	10 4666	16. 7790	
			1: 25000	±4 0	43. 9559	±18 75	65 4160	29. 5800	
			1: 50000	±8 0	175. 8236	±37. 5	261. 6642	59. 1600	
	400~1000	80	1: 5000	±3 0	23. 8443	±3 75	1. 0654	14. 1166	扇形公式计算
			1: 10000	±3 5	23. 8443	±7. 5	4. 2616	14. 9949	
			1: 25000	±4 0	42. 3899	±18 75	26 6349	23. 4989	
			1: 50000	±8 0	169. 5598	±37. 5	106 5398	46. 9978	
	1000~2000	150	1: 5000	±3 0	9. 5251	±3 75	0. 3583	8. 892	扇形公式计算
			1: 10000	±3 5	9. 5251	±7. 5	1. 4333	9. 3631	
			1: 25000	±4 0	16. 9334	±18 75	8. 9584	14. 3922	
			1: 50000	±8 0	67. 7338	±37. 5	35 8335	28. 7843	

注: 平面位置中误差不超过地形图 0. 8 mm; 高程中误差为基本等高距的 2/3。

表 4 估算地形改正误差 ($10^{-8}m/s^2$)统计表(丘陵)

Tab. 4 Error statistic table of the terrain correction tables (Hills) with estimation

0 m~20 m		20 m~200 m		200 m~2 000 m		备注
比例尺	地改精度	比例尺	地改精度	比例尺	地改精度	地改总精度
1: 500	±5. 6611	1: 1000	±8. 7426	1: 5000	±11. 4260	15 4607
1: 1000	±7. 1156	1: 2000	±9. 7975	1: 10000	±13 1777	17. 8962
1: 2000	±9. 3416	1: 5000	±20. 8378	1: 25000	±26 1131	34 6897
	±9. 3416	1: 10000	±27. 8164	1: 50000	±52 2261	59. 9048

表 5 估算地形改正误差 (10^{-8}m /s^2)统计表 (山地)

Tab. 5 Error statistic table of the terrain correction tables (Mountain) with estimation

0 m ~ 20 m		20 m ~ 200 m		200 m ~ 2 000 m		备注
比例尺	地改误差	比例尺	地改误差	比例尺	地改误差	地改总精度
1: 500	±6. 8435	1: 1 000	±12. 4206	1: 5 000	±22 2953	26 4232
1: 1 000	±11. 2520	1: 2 000	±19. 1676	1: 10 000	±24 3731	32 9856
1: 2000	±21. 1198	1: 5 000	±39. 2275	1: 25 000	±33 1154	55 5110
	±21. 1198	1: 10 000	±49. 5884	1: 50 000	±80 8532	97. 1715

表 6 地形改正精度与地形图对应表

Tab. 6 Corresponding table of precision of terrain correction and topographic map

地形改正均方误差	0 m ~ 20 m			20 m ~ 200 m			200 m 以远		
	比例尺	高程精度	平面精度	比例尺	高程精度	平面精度	比例尺	高程精度	平面精度
0. 017	1: 500 1: 1000	±0. 5 ±0. 7	±0. 3 ±0. 6	1: 1000 1: 2000	±0 7 ±0 7	±0 6 ±1 2	1: 5000 1: 10000	±1. 5 ±1. 5	±2 5 ±5 0
0. 035	1: 500 1: 1000 1: 2000	±0. 7 ±1. 0 ±1. 5	±0. 4 ±0. 8 ±1. 6	1: 1000 1 1: 2000 1: 5000	±0 7 ±0 7 ±1 5	±0 6 ±1 2 ±2 5	1: 5000 1: 10000 1: 25000	±1. 5 ±1. 5 ±2 5	±2 5 ±5 0 ±12 5
0 07	1: 500 1: 1000 1: 2000	±0. 7 ±1. 0 ±1. 5	±0. 4 ±0. 8 ±1. 6	1: 1000 1: 2000 1: 5000 1: 10000	±0 7 ±0 7 ±1 5 ±1 5	±0 8 ±1 6 ±3 75 ±7. 5	1: 5 000 1: 10000 1: 25000 1: 10000	±3. 0 ±3. 0 ±4. 0 ±8. 0	±2 5 ±5 0 ±12. 5 ±25. 0
0 11	1: 500 1: 1000 1: 2000	±0. 7 ±1. 0 ±1. 5	±0. 4 ±0. 8 ±1. 6	1: 1000 1: 2000 1: 5000 1: 10000	±1 0 ±1 5 ±3 0 ±3 0	±0 8 ±1 6 ±3 75 ±7. 5	1: 5000 1: 10000 1: 25000 1: 50000	±3. 0 ±3. 0 ±4. 0 ±8. 0	±3 75 ±7. 50 ±18 75 ±37. 50

注: 地形改正均方误差单位 10^{-5} m /s^2; 高程、平面精度 m。

3 结论

(1)在利用地形图读图计算重力地形改正时,其精度取决于读出的平面及高程精度。在地形条件相同的情况下,地形图比例尺越大,读图精度越高,计算重力地形改正精度越高。

(2)当地形图比例尺相同时,地形越平缓,地形图本身的精度就越高,读图精度越高,计算重力地形改正精度越高。

(3)同样精度的地形条件,测点与周围的高差越大,地形改正误差越大。

(4)在实际工作中,利用地形图读图方式进行重力近区地形改正时,选择地形图要考虑比例尺,同时还应考虑测点所处地形条件,只有这样,其精度才能满足工作设计地形改正精度。

(5)大比例尺重力勘查实际工作中,设计的地形改正精度所需地形图比例尺及高程、平面精度,可参考表 6确定。

(6)以上结论只是利用地形图读图方法计算重力地形改正时,圆锥、扇形公式用平均高差的误差估算。

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work construction and test of geophysical work deployment So scientific and reasonable, accurate exploration work can be carried out to improve geophysical efficiency.

Key words "3S" technology; location survey of geophysical measurements; optimizing method

GRAVITY NEAR ZONE TERRAIN CORRECTION PRECISION DISCUSSION

YANG Ya-bin, HAN Ge-ming, LIANG Meng (Institute of Geophysics and Geochemical Exploration, Langfang 065000, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2011, 33(1): 92

Working in Large-scale gravity exploration, the influence of short range terrain correction and intermediate area topographic correction error on gravity precision is great In reality, short range terrain correction is calculated on actual measurement or using relief map, and intermediate area topographic is calculated on using relief map, "The standard for large-scale gravity survey" only consider the influence of terrain elevation precision on gravity precision, but ignores the influence of relief map precision On the basis of formula of terrain correction, we discuss the influence of scale, elevation and plane precision on gravity precision We put forward some suggestions on the demand on scale, elevation and plane precision basis on terrain correction precision.

Key words terrain correction; elevation precision; plane precision; scale

THE INTEGRATION OF THREE DIMENSION GEOLOGICAL MODELING AND GEOGRAPHIC INFORMATION SYSTEM

LI Fang-yu (State Key Laboratory of Petroleum Resources and Prospecting China University of Petroleum, Beijing 102249, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2011, 33(1): 97

The application objectives of 3D GM and GIS are different, so their research focuses are different Their integration can promote their development, but the systemic research on their integration is little The paper compares and analyses their function and indicates the significance of the integration Then the paper propose the ways of the integration and analyses their merits At last, the paper forecasts the development trends of their integration

Key words 3D GIS; 3D geological modeling; integration

RESEARCH ON THE INVERSION ALGORITHMS OF THE β IN THE PURE SHEAR MODEL

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The previous algorithms of stretching factor inversion are based on single-well data fitting the calibration, and has almost researched the incorporation of structure and thermal evolution This article uses the pure shear model formula of calculating subsidence and heat flow, which McKenzie put forward in the 1978 Based on the idea of one-dimensional inversion stretch factors, this paper uses the GUI function of Matlab software compiling the interface of the multipoint inversion of stretching factors, and reduces the work load which makes the false well data in the inversion of stretching factors As the example of the survey line of SO49-25 in north-central area of the south China sea, this paper calculates the stretch factors and paleo-heat flow and verifies the feasibility of the algorithm.

Key words pure shear model; stretching factor; inversion

GOOGLE EARTH-BASED NUCLEAR DATA PROCESSING WITH E-LANGUAGE

LI Fei, GE Liang-quan, MA Ying-jie (Chengdu University of Technology, Chengdu Sichuan 610059, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2011, 33(1): 107

The direction of this study is to use integrated module of E-language to edit, to achieve the processing and display of mass nuclear exploration point information in the Google Earth platform, that is, to use the powerful visualization google Earth platform and the intuition of KML module, the entire programming is completed by E-language The nuclear survey data can be directly read and changed and invokes the KML module integrated in E-language environment, then be written as KML data format identified by Google Earth Different modules can be used to achieve different functions according to actual situations, this powerful Google Earth platform will open a new chapter for the nuclear investigation

Key words Google Earth; KML; E-language