智能多层位同步解释技术

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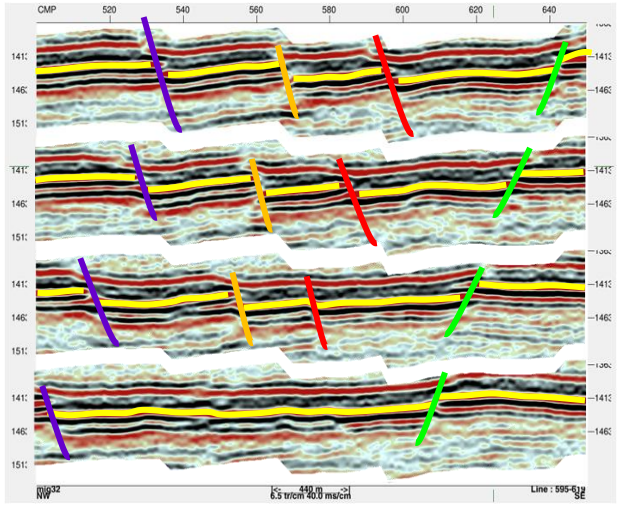
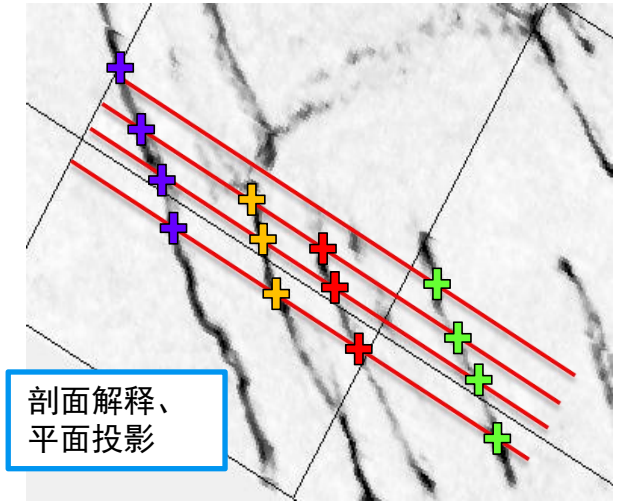
2025年10月22日

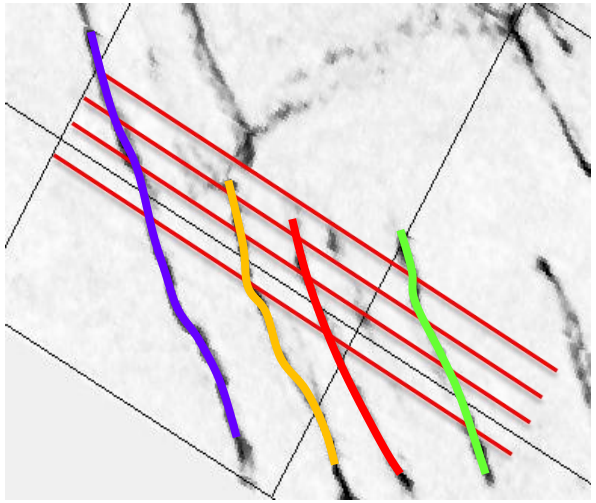
传统层位解释技术

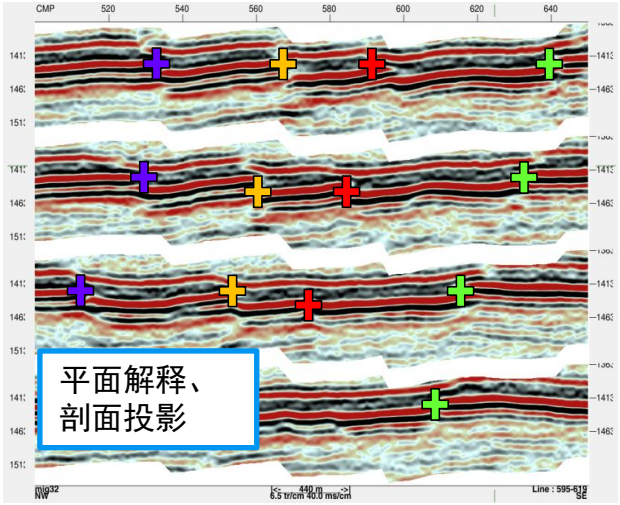
多线剖面解释





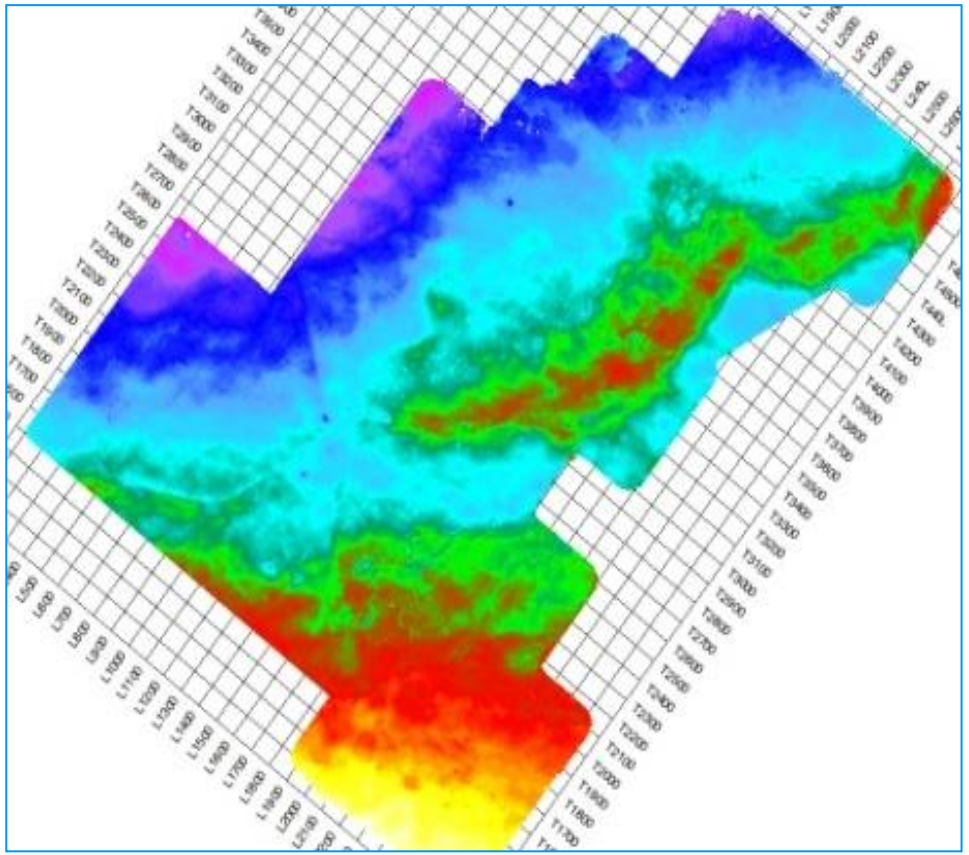
剖面解释、
平面投影





平面解释、
剖面投影

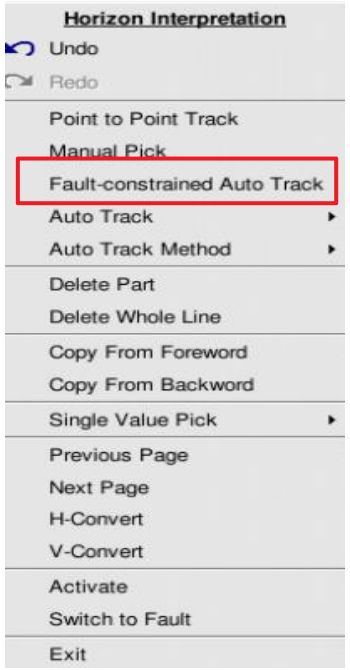
高效三维层位自动追踪技术

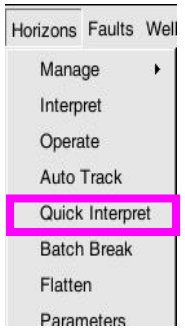


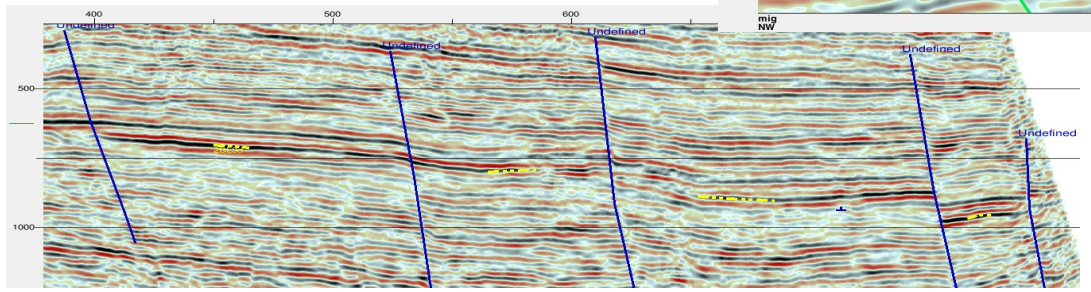
概 述

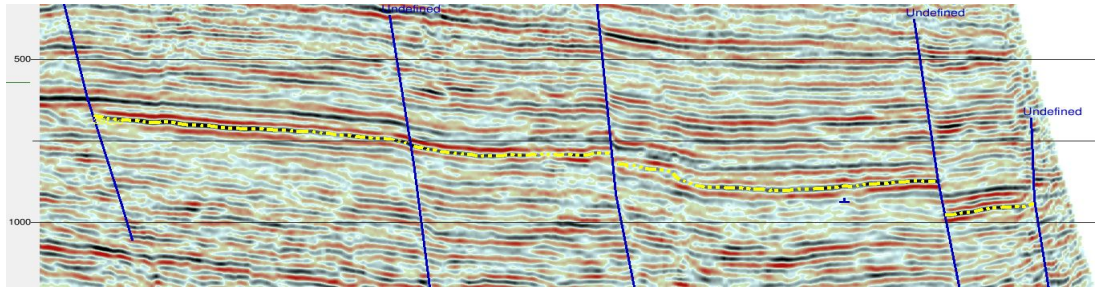
断层阻挡的层位自动追踪(3d):选择该功能后,当前剖面的激活层进行全剖面的自动追踪,追踪的层位段在遇到剖面显示的断层时自动中止并搭接到断层

断层阻挡的层位自动追踪(3d)

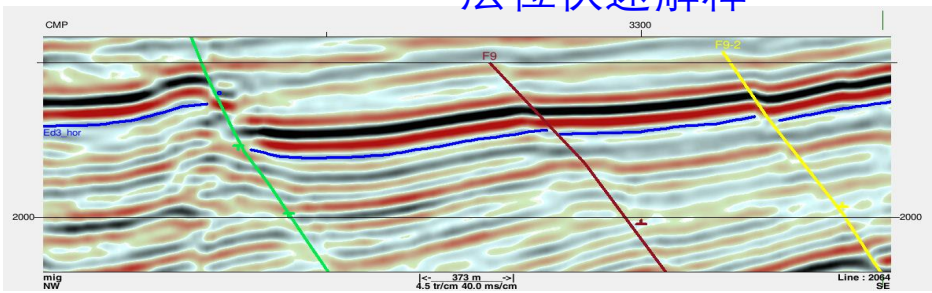


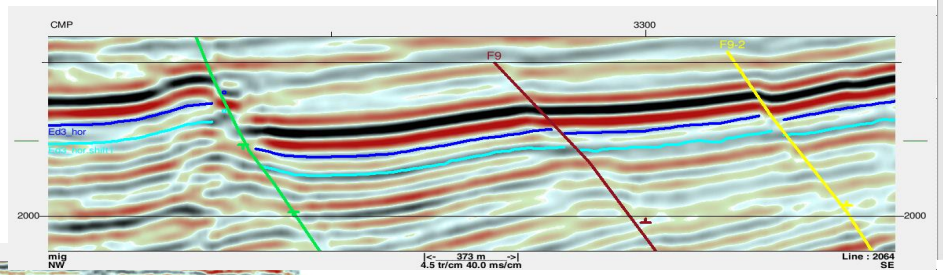


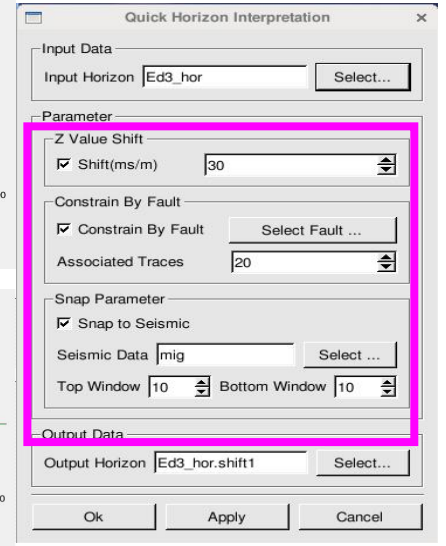




层位快速解释





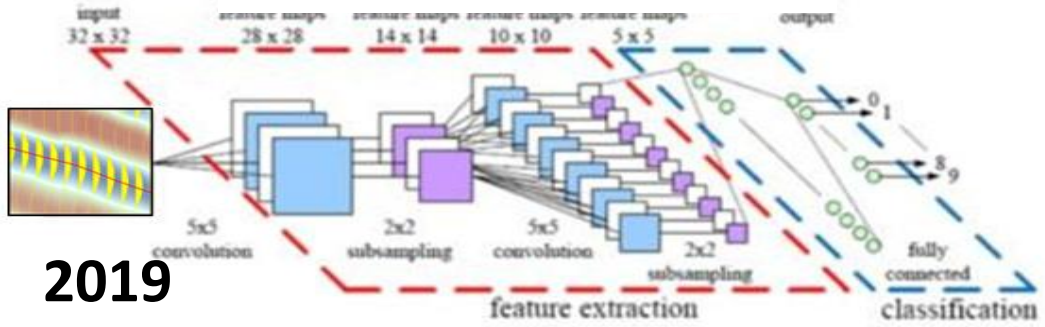


断层控制下的层间小层自动解释—对层位进行时移，可沿着断层进行剪切延伸，并可以根据数据体对层位进行归位

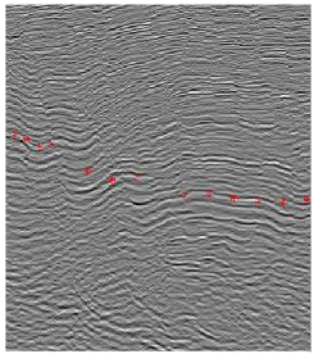
概 述

基于深度学习方法的人工智能层位追踪解释技术

卷积神经网络+分类算法

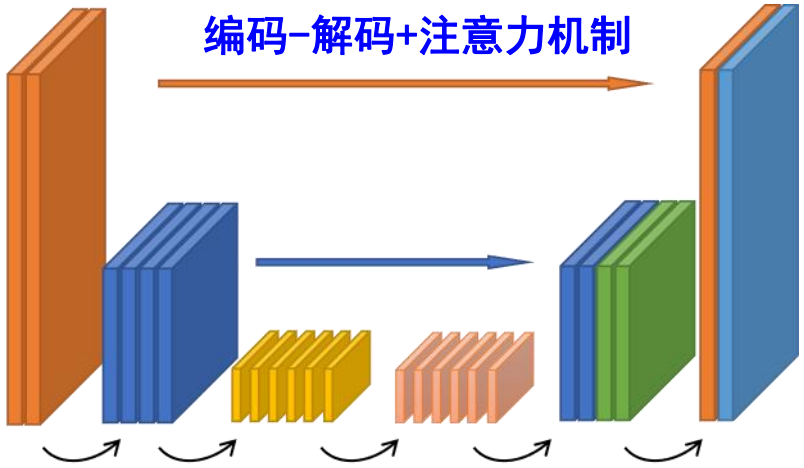


2019



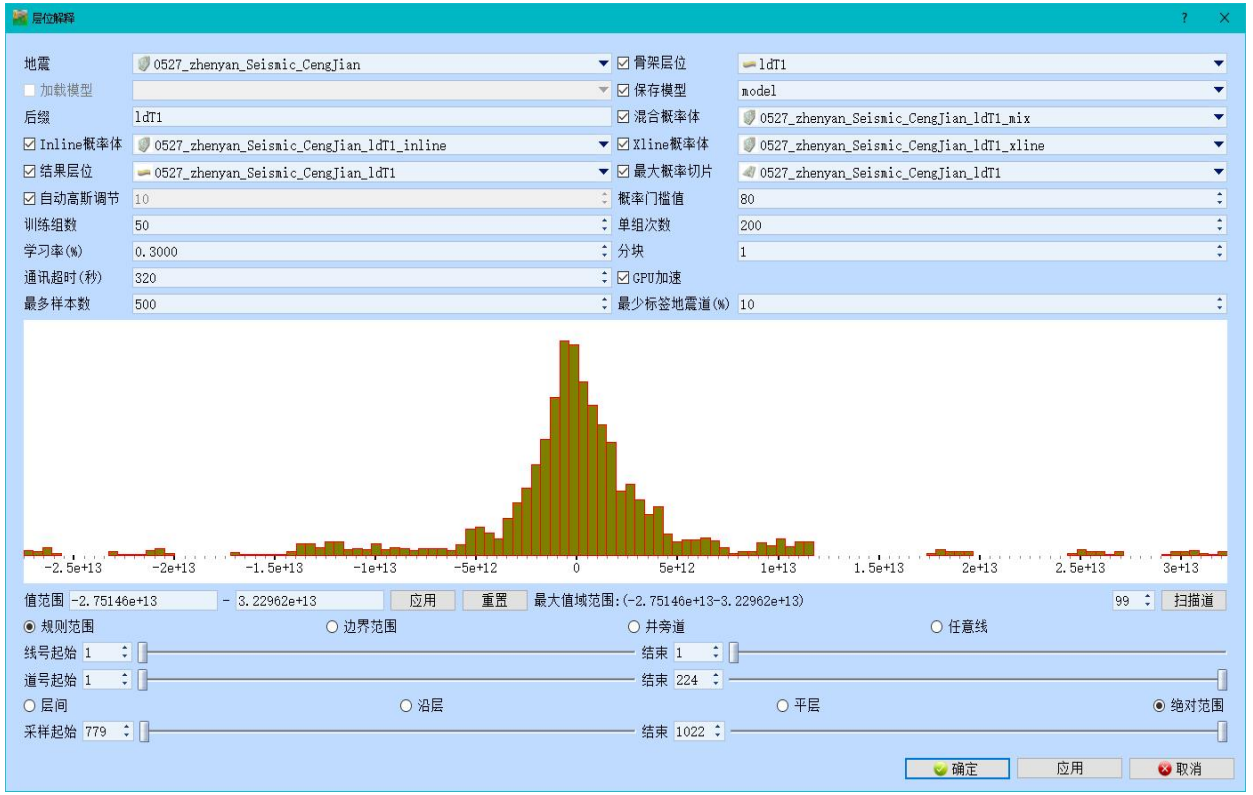
2020

编码-解码+注意力机制



编码Encoder
（提取多尺度特征）

解码Encoder
（多尺度层位识别）



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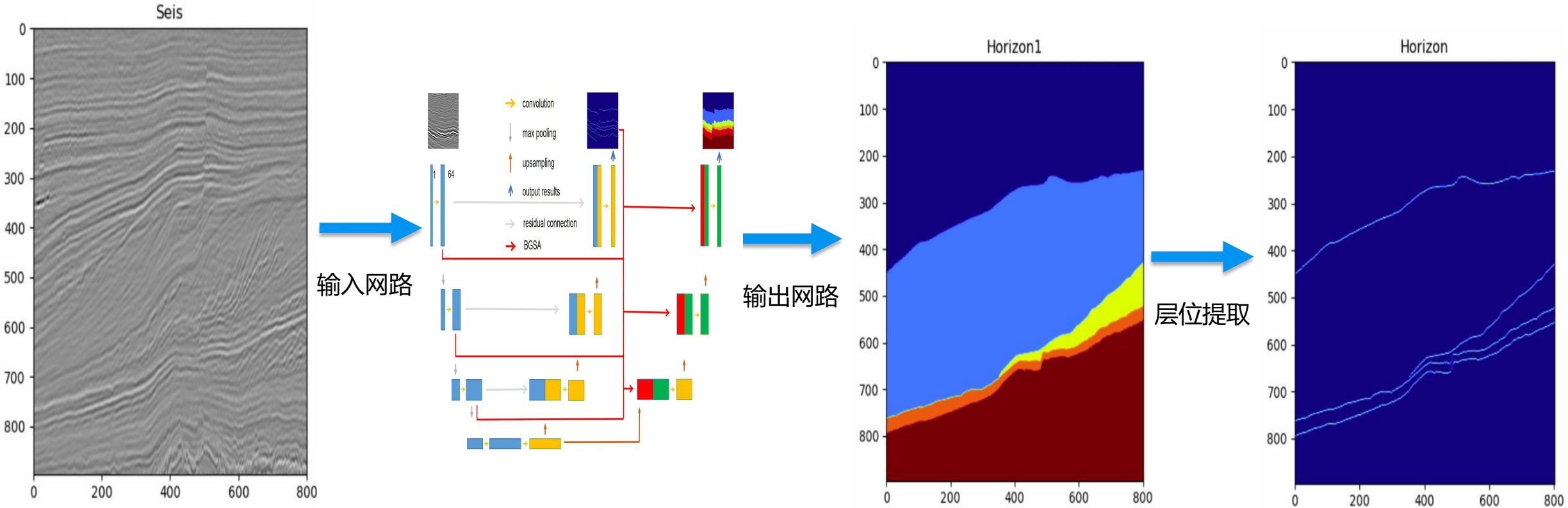
方法原理

基于计算机视觉的语义分割理论，构建多尺度多任务深度神经网络模型，并通过随机掩码增强网络模型抗噪能力，实现地震数据多层位同步约束拾取功能。

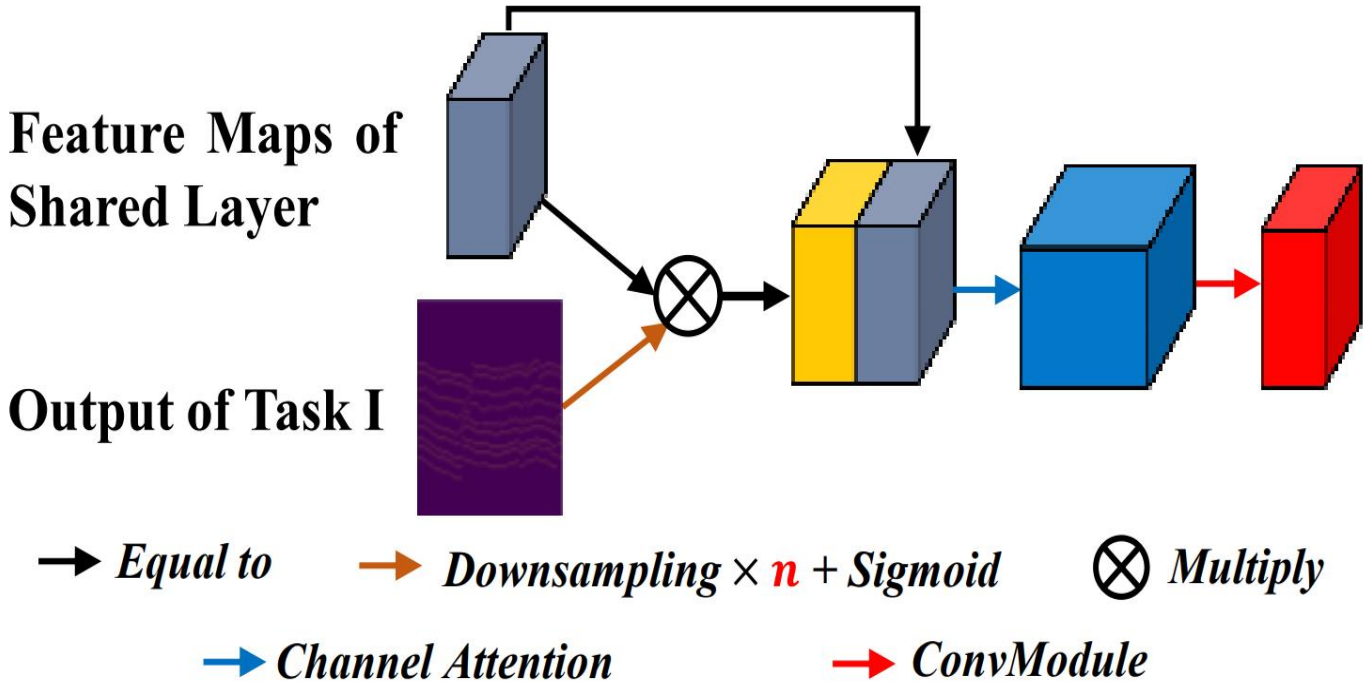


地震数据　　网络模型　　语义分割　　层位拾取

方法原理

为了充分利用由辅助任务提取的层位边界信息，使用了一种浅层特征引导模块（BGSA）。该模块有效提升了主网络对地震层位的拾取精度。

- 提高非显著性目标特征的提取能力，抑制噪声的干扰。



利用浅层信息结合辅助任务的输出结果，精确定位层位边界

方法原理

1）主任务损失L_1-- 基于交叉熵损失

$$Loss_k(x,y) = -\frac{1}{M}\sum_{m=1}^{M}\left[R_k(m) \times log[s_k(m)] + [1 - R_k(m)] \times log[1 - s_k(m)]\right] \quad (1)$$

$$L_1(x,y) = -\frac{1}{K}\sum_{k=1}^{K} Loss_k(x,y) \quad (2)$$

x, y, m：分别代表三维地震数据中的三个维度

M：总的时间范围

K：目标层位数

$R_k(m)$：(x, y, m)位于第k个地层时为1，不在第k个地层时为0

$s_k(m)$：主任务得到的第k个目标层位的地层跟踪结果

2）辅助任务损失L_2

与L_1 类似，基于交叉熵损失

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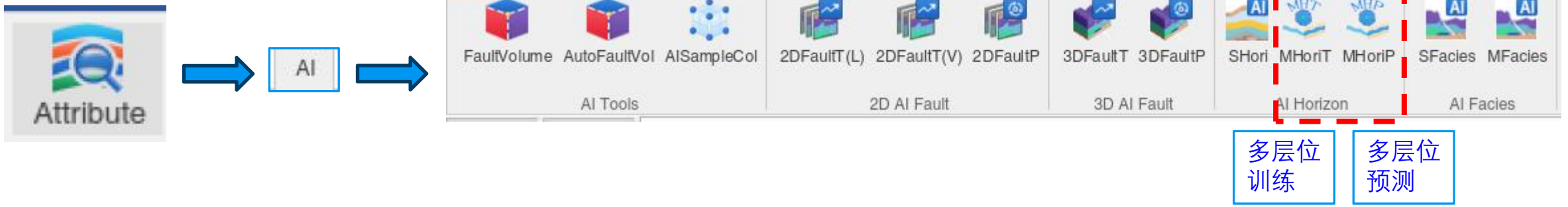
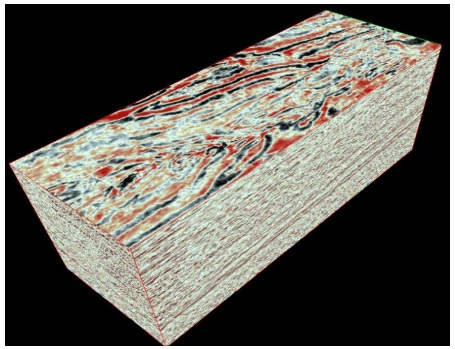
模块界面及参数 — 启动位置

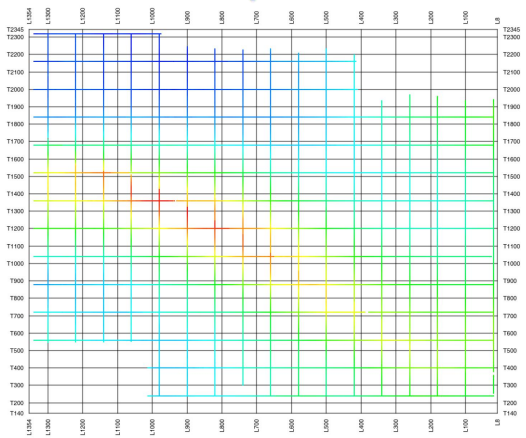


OR

模块界面及参数 – 应用流程

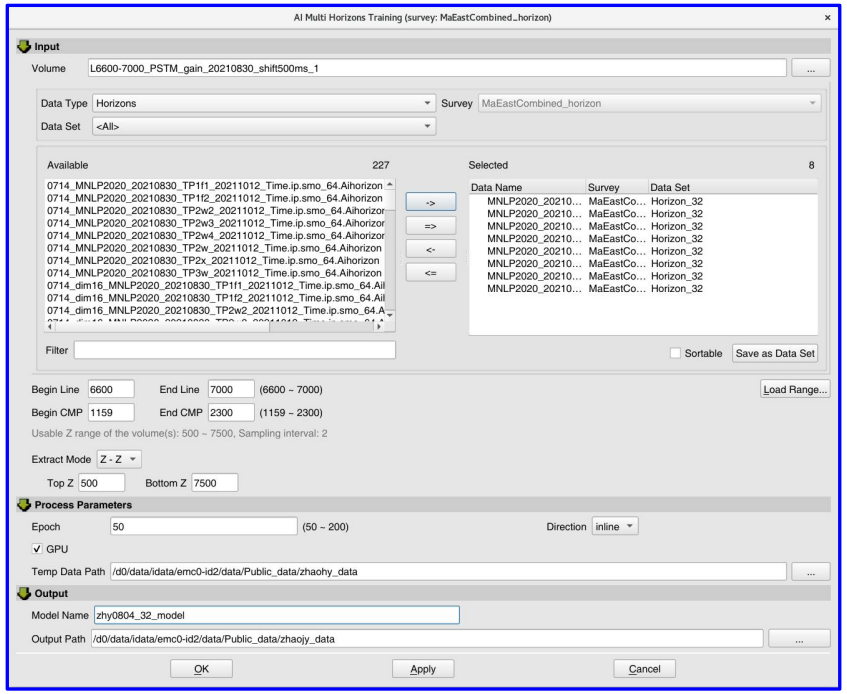


地震数据

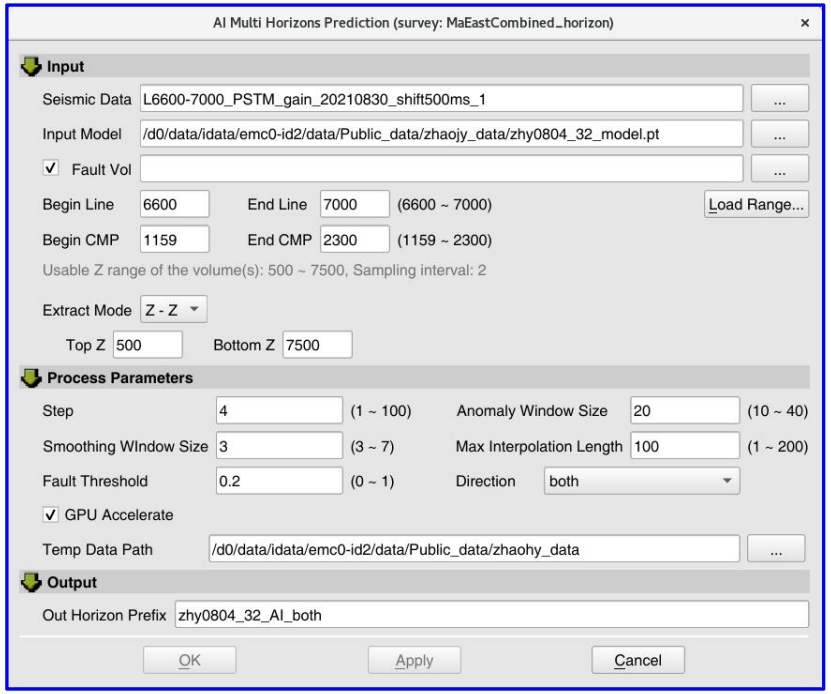


骨架层位

MHoriT

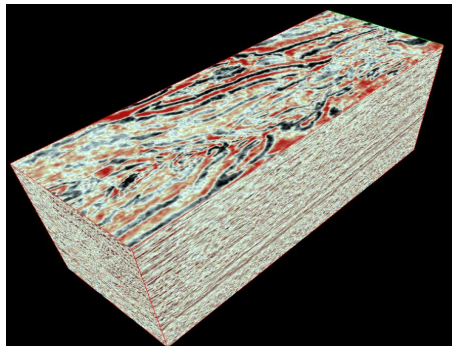


MHoriP

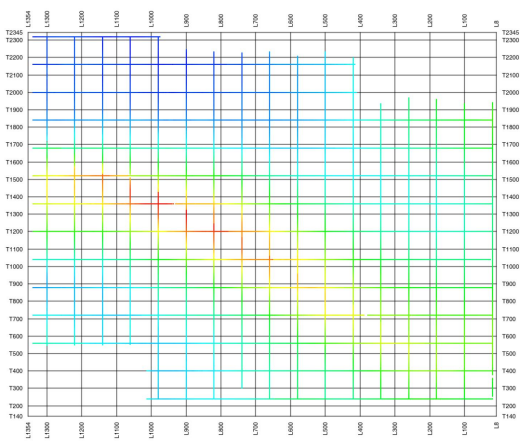


①数据准备 → ②AI多层位训练 → ③AI多层位预测

模块界面及参数 – 数据准备



地震数据

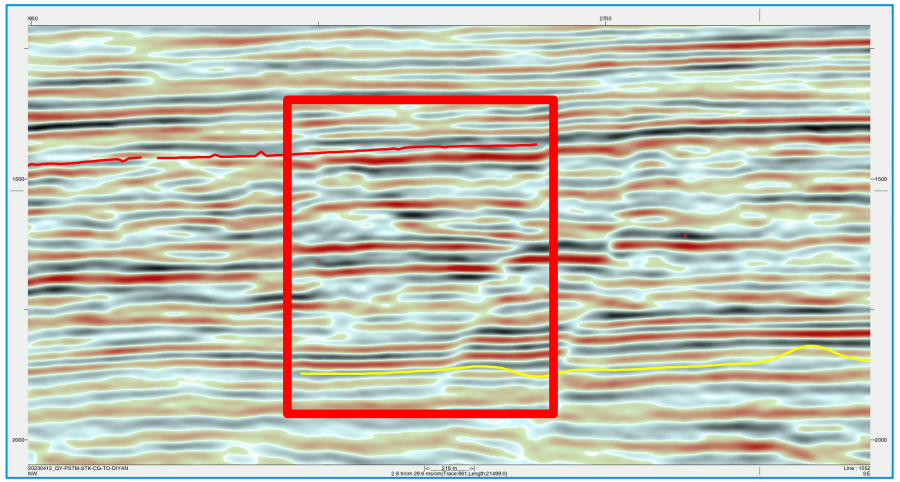


骨架层位

地震数据： 优选2ms（cmp范围几千），选择4ms采样，层位归位不准确，速度并不会提高太多，选择1ms采样（cmp范围几百），预测结果更精细

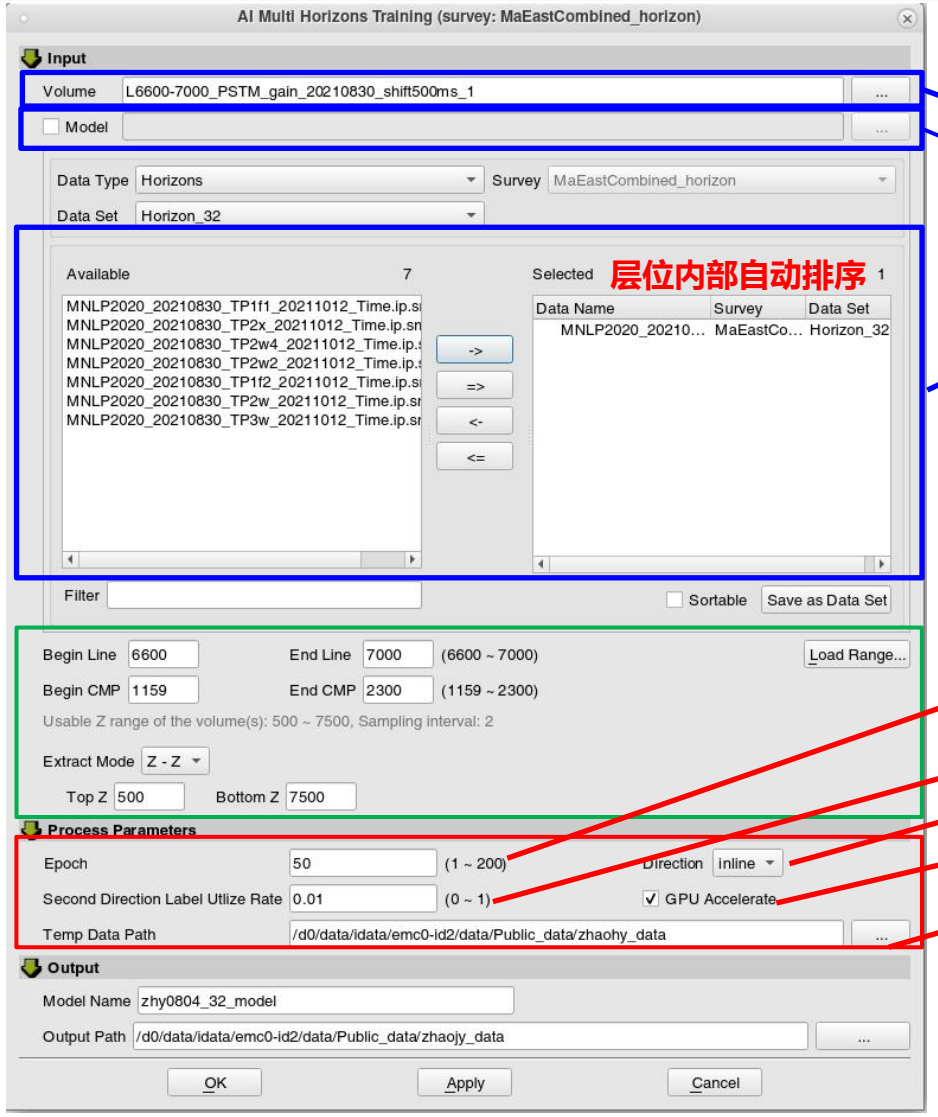
标签层位： 取交集，要求解释范围尽量一致，另一个方向也有部分标签，闭合性会更好

解释密度保持一致，如果不同层位存在不同解释密度，最终标签采纳的是最稀疏解释密度



建议： 骨架剖面中每个层位解释全面完整

模块界面及参数 – 模型训练 – 界面参数



输入：

Volume： 训练的地震数据

Model: 指定的预训练模型（勾选）还是内置的预训练模型（不勾选）

Selected: 选中的用于训练的骨架层位，

标签层位取交集，另一个方向也有部分标签，闭合性会更好

范围：训练与预测范围需要保持一致，纵向范围在层位最大最小范围基础上进行拓展

主要参数：

Epoch：迭代次数（10~200）默认50

取决于标签层位多少，由于做了数据增广，所以Epoch可以给大一些

Second Direction Label Utilize Rate： 第二个方向标签利用率

越大越耗时，建议0.01左右。默认值0.01。

Direction： 层位训练方向，

目前可以沿着inline或者crossline，没有both方向

GPU Acceleration : 是否采用GPU加速训练

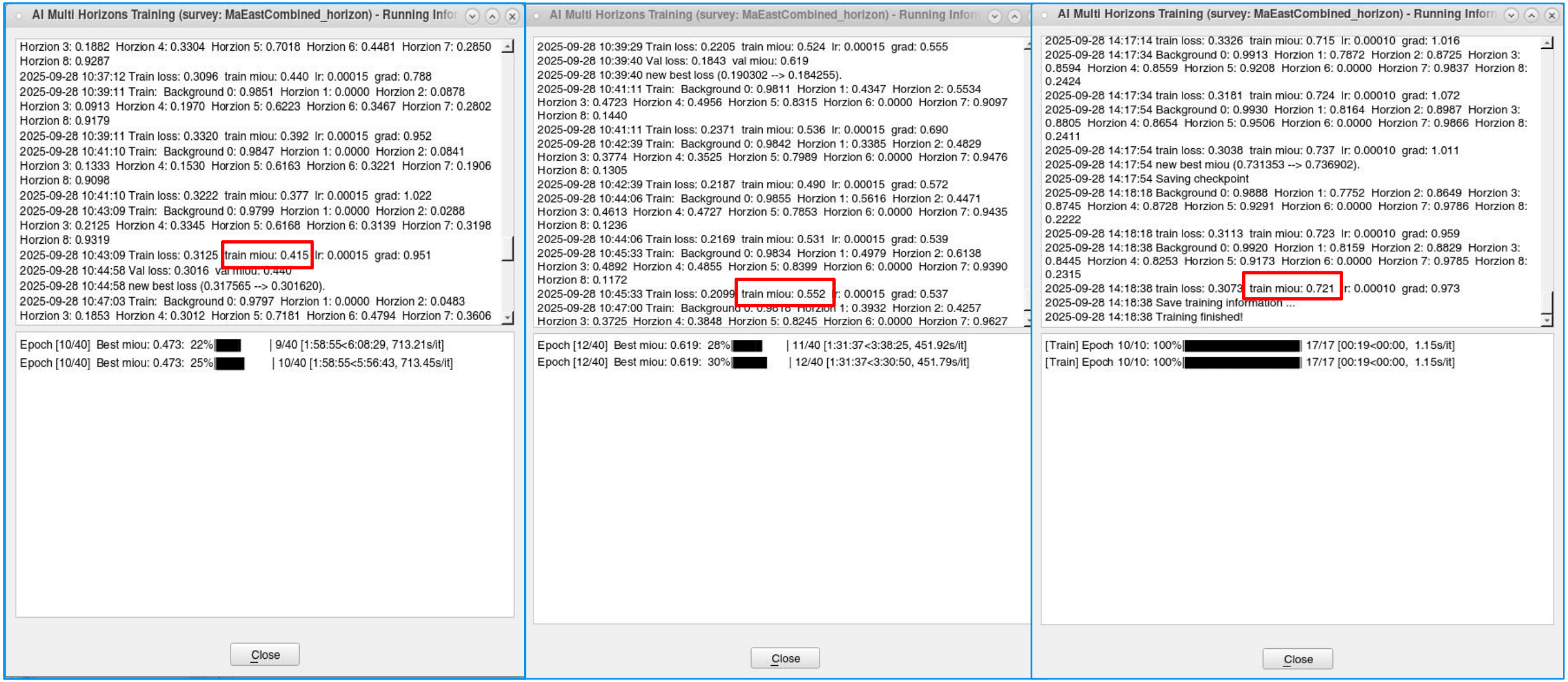
Temp Data Path：临时路径

注意事项：

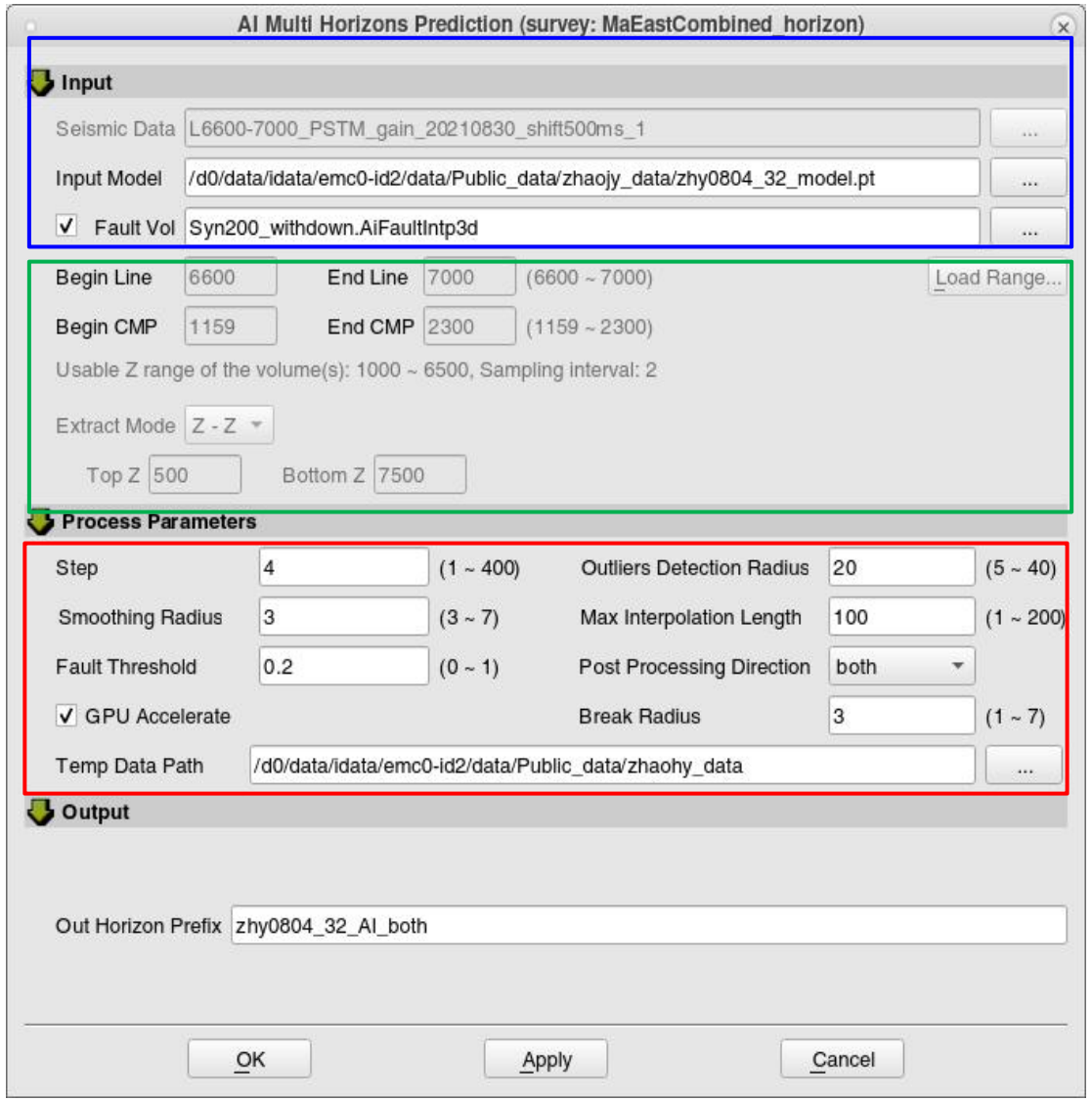
1. 起始时间和终止时间要给大一点，不然会报错，需要大于层位的最大值和小于层位的最小值。

2.如果同时两个进程，不可以选择同一个临时路径

模型训练效果监测


AI Multi Horizons Training (survey: MaEastCombined_horizon) - Running Infor
Horzion 3: 0.1882 Horzion 4: 0.3304 Horzion 5: 0.7018 Horzion 6: 0.4481 Horzion 7: 0.2850 Horzion 8: 0.9287
2025-09-28 10:37:12 Train loss: 0.3096 train miou: 0.440 lr: 0.00015 grad: 0.788
2025-09-28 10:39:11 Train: Background 0: 0.9851 Horzion 1: 0.0000 Horzion 2: 0.0878 Horzion 3: 0.0913 Horzion 4: 0.1970 Horzion 5: 0.6223 Horzion 6: 0.3467 Horzion 7: 0.2802 Horzion 8: 0.9179
2025-09-28 10:39:11 Train loss: 0.3320 train miou: 0.392 lr: 0.00015 grad: 0.952
2025-09-28 10:41:10 Train: Background 0: 0.9847 Horzion 1: 0.0000 Horzion 2: 0.0841 Horzion 3: 0.1333 Horzion 4: 0.1530 Horzion 5: 0.6163 Horzion 6: 0.3221 Horzion 7: 0.1906 Horzion 8: 0.9098
2025-09-28 10:41:10 Train loss: 0.3222 train miou: 0.377 lr: 0.00015 grad: 1.022
2025-09-28 10:43:09 Train: Background 0: 0.9799 Horzion 1: 0.0000 Horzion 2: 0.0288 Horzion 3: 0.2125 Horzion 4: 0.3345 Horzion 5: 0.6168 Horzion 6: 0.3139 Horzion 7: 0.3198 Horzion 8: 0.9319
2025-09-28 10:43:09 Train loss: 0.3125 train miou: 0.415 lr: 0.00015 grad: 0.951
2025-09-28 10:44:58 Val loss: 0.3016 val miou: 0.440
2025-09-28 10:44:58 new best loss (0.317565 --> 0.301620).
2025-09-28 10:47:03 Train: Background 0: 0.9797 Horzion 1: 0.0000 Horzion 2: 0.0483 Horzion 3: 0.1853 Horzion 4: 0.3012 Horzion 5: 0.7181 Horzion 6: 0.4794 Horzion 7: 0.3606
Epoch [10/40] Best miou: 0.473: 22%| | 9/40 [1:58:55<6:08:29, 713.21s/it]
Epoch [10/40] Best miou: 0.473: 25%| | 10/40 [1:58:55<5:56:43, 713.45s/it]
Close
AI Multi Horizons Training (survey: MaEastCombined_horizon) - Running Infor
2025-09-28 10:39:29 Train loss: 0.2205 train miou: 0.524 lr: 0.00015 grad: 0.555
2025-09-28 10:39:40 Val loss: 0.1843 val miou: 0.619
2025-09-28 10:39:40 new best loss (0.190302 --> 0.184255).
2025-09-28 10:41:11 Train: Background 0: 0.9811 Horzion 1: 0.4347 Horzion 2: 0.5534 Horzion 3: 0.4723 Horzion 4: 0.4956 Horzion 5: 0.8315 Horzion 6: 0.0000 Horzion 7: 0.9097 Horzion 8: 0.1440
2025-09-28 10:41:11 Train loss: 0.2371 train miou: 0.536 lr: 0.00015 grad: 0.690
2025-09-28 10:42:39 Train: Background 0: 0.9842 Horzion 1: 0.3385 Horzion 2: 0.4829 Horzion 3: 0.3774 Horzion 4: 0.3525 Horzion 5: 0.7989 Horzion 6: 0.0000 Horzion 7: 0.9476 Horzion 8: 0.1305
2025-09-28 10:42:39 Train loss: 0.2187 train miou: 0.490 lr: 0.00015 grad: 0.572
2025-09-28 10:44:06 Train: Background 0: 0.9855 Horzion 1: 0.5616 Horzion 2: 0.4471 Horzion 3: 0.4613 Horzion 4: 0.4727 Horzion 5: 0.7853 Horzion 6: 0.0000 Horzion 7: 0.9435 Horzion 8: 0.1236
2025-09-28 10:44:06 Train loss: 0.2169 train miou: 0.531 lr: 0.00015 grad: 0.539
2025-09-28 10:45:33 Train: Background 0: 0.9834 Horzion 1: 0.4979 Horzion 2: 0.6138 Horzion 3: 0.4892 Horzion 4: 0.4855 Horzion 5: 0.8399 Horzion 6: 0.0000 Horzion 7: 0.9390 Horzion 8: 0.1172
2025-09-28 10:45:33 Train loss: 0.2099 train miou: 0.552 lr: 0.00015 grad: 0.537
2025-09-28 10:47:00 Train: Background 0: 0.9818 Horzion 1: 0.3932 Horzion 2: 0.4257 Horzion 3: 0.3725 Horzion 4: 0.3848 Horzion 5: 0.8245 Horzion 6: 0.0000 Horzion 7: 0.9627
Epoch [12/40] Best miou: 0.619: 28%| | 11/40 [1:31:37<3:38:25, 451.92s/it]
Epoch [12/40] Best miou: 0.619: 30%| | 12/40 [1:31:37<3:30:50, 451.79s/it]
Close
AI Multi Horizons Training (survey: MaEastCombined_horizon) - Running Infor
2025-09-28 14:17:14 train loss: 0.3326 train miou: 0.715 lr: 0.00010 grad: 1.016
2025-09-28 14:17:34 Background 0: 0.9913 Horzion 1: 0.7872 Horzion 2: 0.8725 Horzion 3: 0.8594 Horzion 4: 0.8559 Horzion 5: 0.9208 Horzion 6: 0.0000 Horzion 7: 0.9837 Horzion 8: 0.2424
2025-09-28 14:17:34 train loss: 0.3181 train miou: 0.724 lr: 0.00010 grad: 1.072
2025-09-28 14:17:54 Background 0: 0.9930 Horzion 1: 0.8164 Horzion 2: 0.8987 Horzion 3: 0.8805 Horzion 4: 0.8654 Horzion 5: 0.9506 Horzion 6: 0.0000 Horzion 7: 0.9866 Horzion 8: 0.2411
2025-09-28 14:17:54 train loss: 0.3038 train miou: 0.737 lr: 0.00010 grad: 1.011
2025-09-28 14:17:54 new best miou (0.731353 --> 0.736902).
2025-09-28 14:17:54 Saving checkpoint
2025-09-28 14:18:18 Background 0: 0.9888 Horzion 1: 0.7752 Horzion 2: 0.8649 Horzion 3: 0.8745 Horzion 4: 0.8728 Horzion 5: 0.9291 Horzion 6: 0.0000 Horzion 7: 0.9786 Horzion 8: 0.2222
2025-09-28 14:18:18 train loss: 0.3113 train miou: 0.723 lr: 0.00010 grad: 0.959
2025-09-28 14:18:38 Background 0: 0.9920 Horzion 1: 0.8159 Horzion 2: 0.8829 Horzion 3: 0.8445 Horzion 4: 0.8253 Horzion 5: 0.9173 Horzion 6: 0.0000 Horzion 7: 0.9785 Horzion 8: 0.2315
2025-09-28 14:18:38 train loss: 0.3073 train miou: 0.721 lr: 0.00010 grad: 0.973
2025-09-28 14:18:38 Save training information ...
2025-09-28 14:18:38 Training finished!
[Train] Epoch 10/10: 100%| | 17/17 [00:19<00:00, 1.15s/it]
[Train] Epoch 10/10: 100%| | 17/17 [00:19<00:00, 1.15s/it]
Close

模块界面及参数 – 层位预测 – 界面参数



输入：

seismic Data:地震数据

Input Model：训练输出的模型（没有固定位置）

Fault Vol：断裂概率体（可选）

预测范围：与训练保持一致，灰化，不可更改

处理参数：

Step：预测间隔

Outliers Detection Radius:异常检测半径（横向道数）

值越大，检测异常少，值越小，检测异常更多

层位变化不大的时候可以给大点；层位变化大，有断层的时候给小点5左右

Smoothing Window Size：预测结果进行高斯平滑窗口大小

Max Interpolation Length：最大插值长度，

预测结果置信度低的地方，结果不连续，进行横向插值

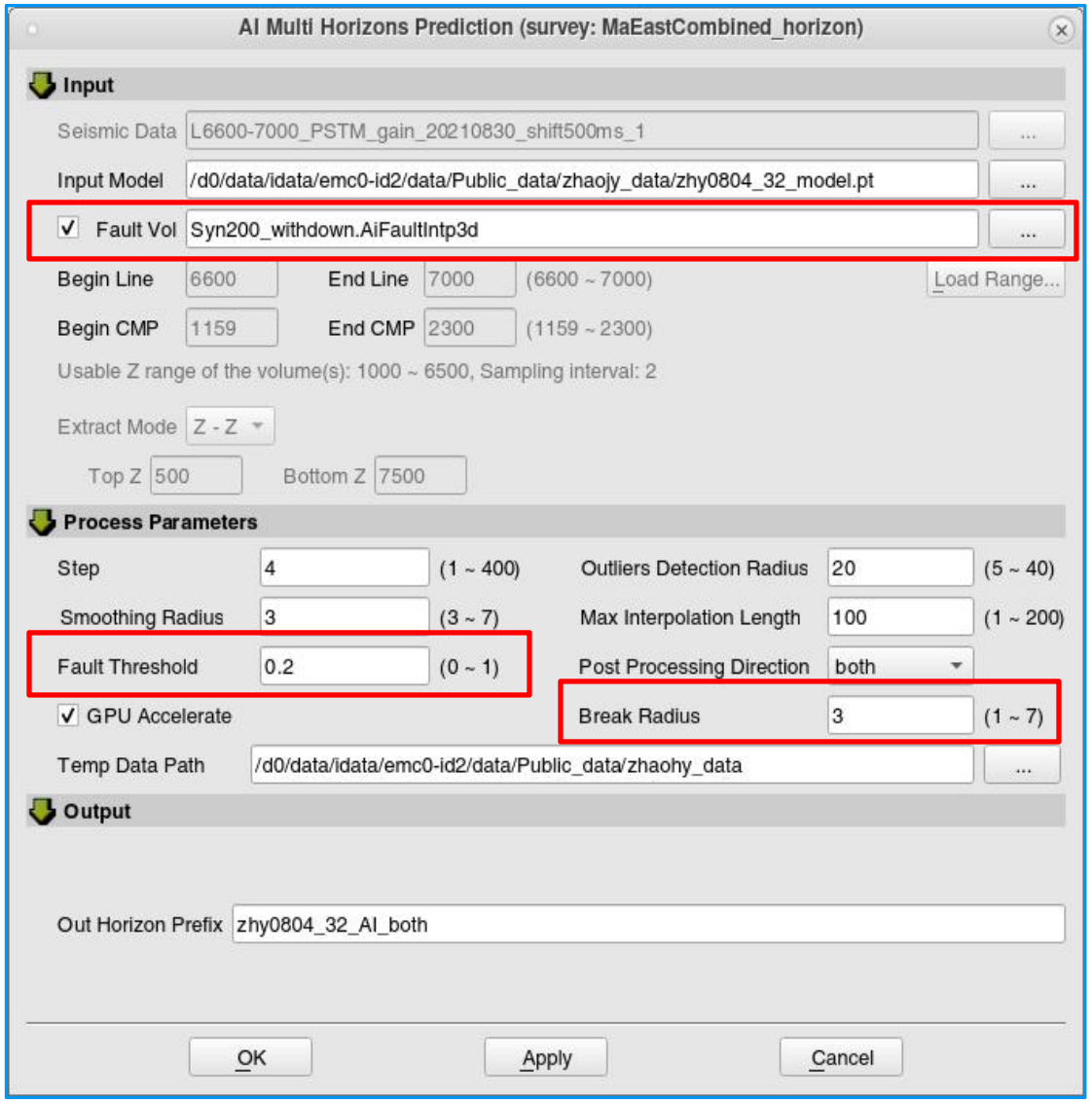
Fault Threshold：断层阈值

Post Processing Direction：后处理方向

Break Radius：断层打断半径

模块界面及参数 – 层位预测 – 界面参数

后处理关联参数

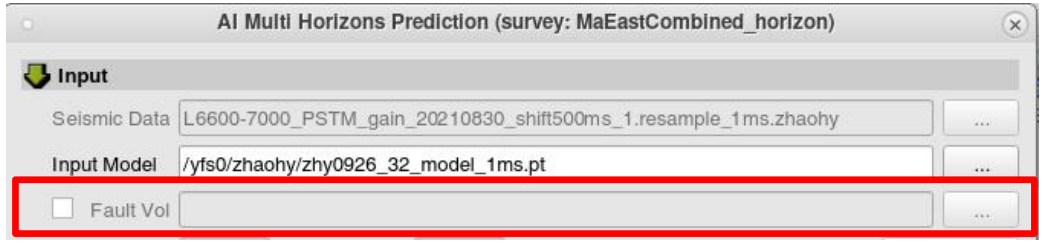


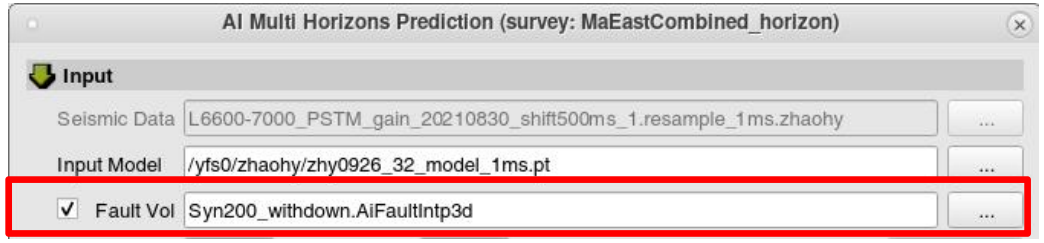
是否使用断裂概率体

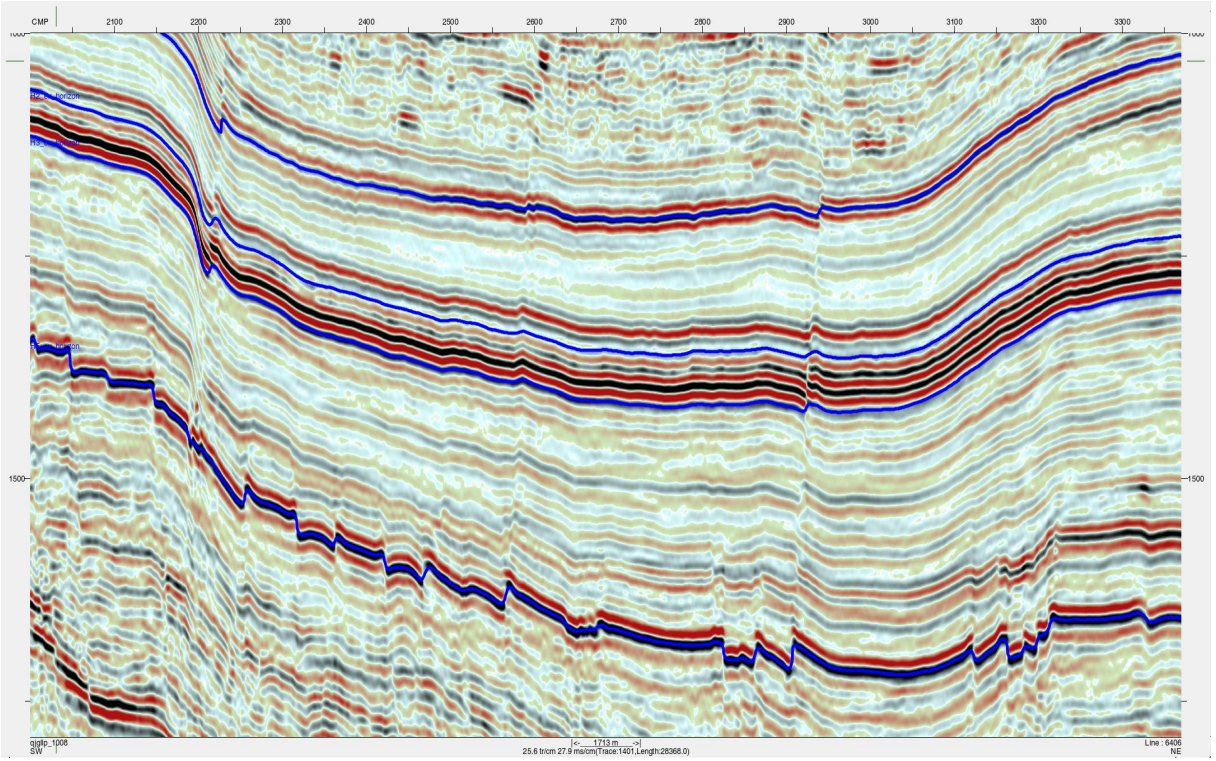
定义断裂概率体中断层阈值

层位打断半径

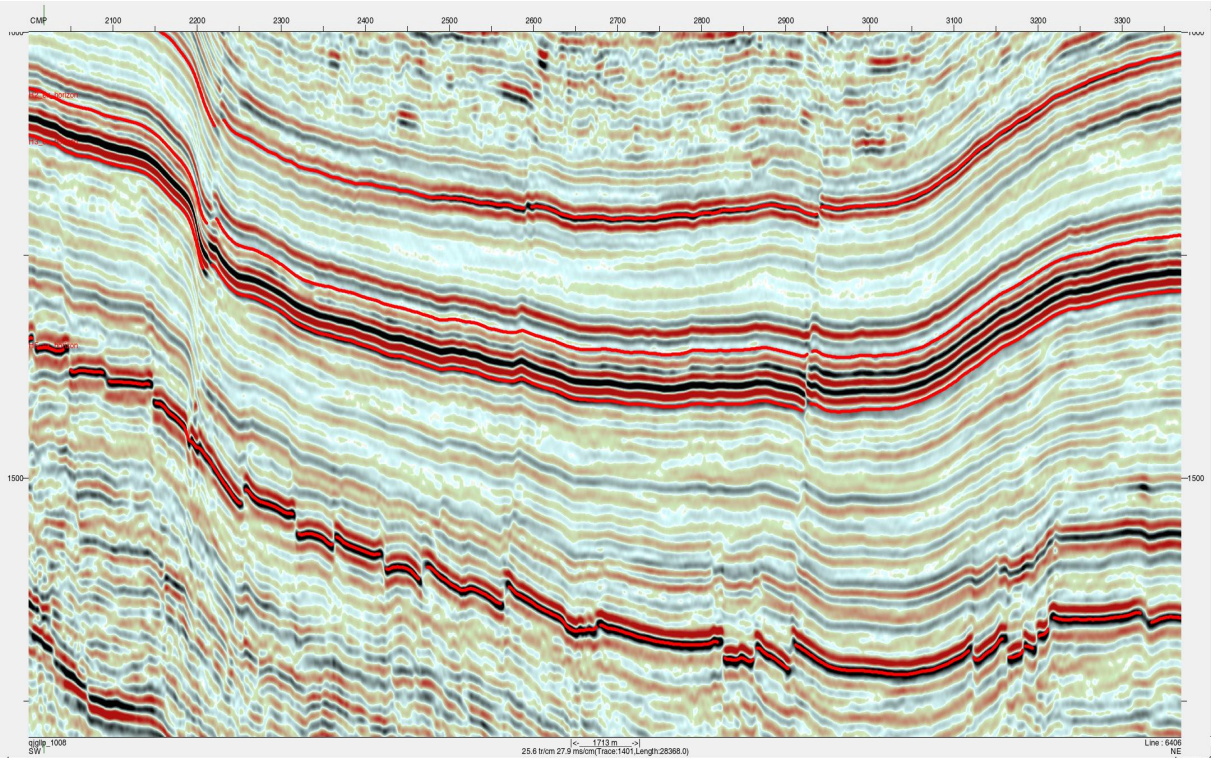
模块界面及参数 – 层位预测 – 界面参数







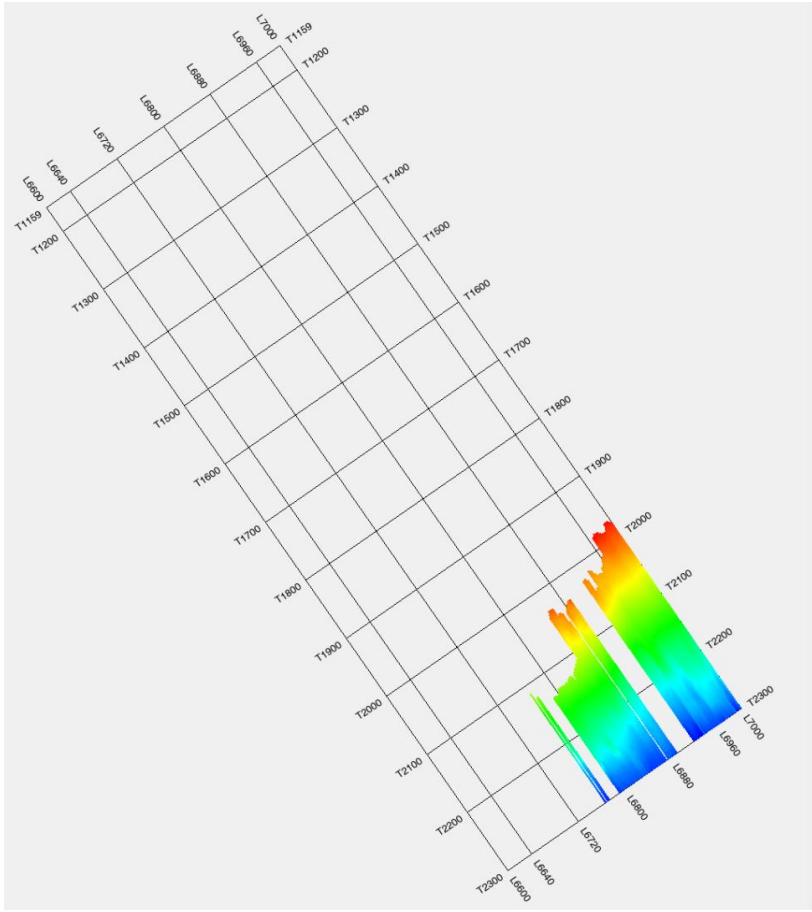
断点处未断开



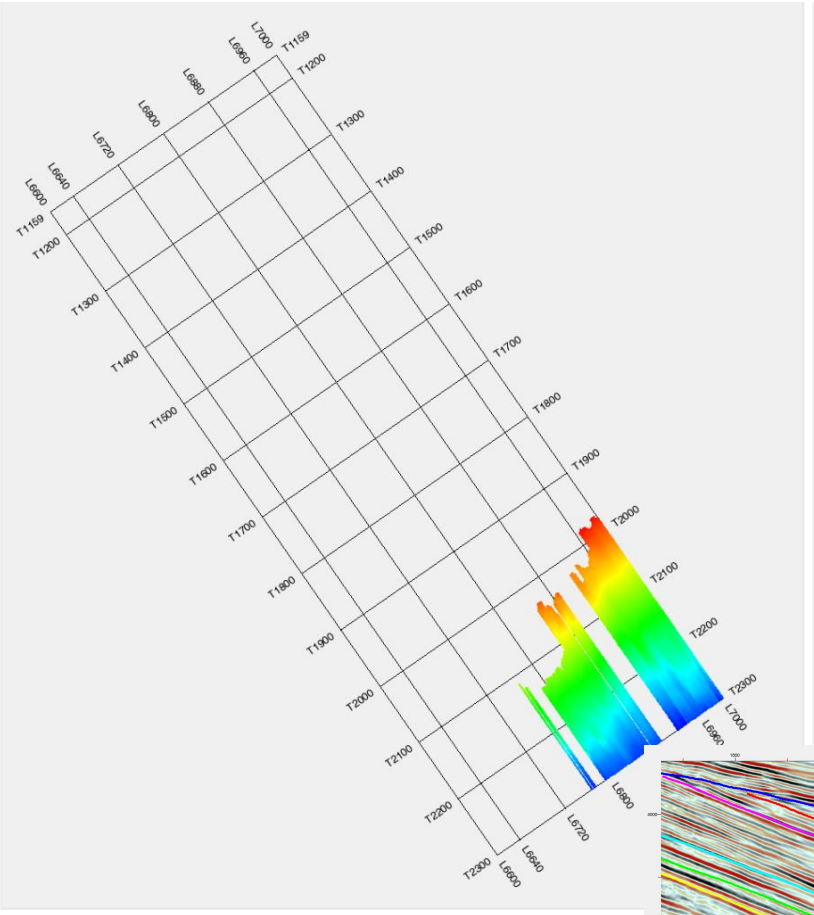
断点处断开

参数影响

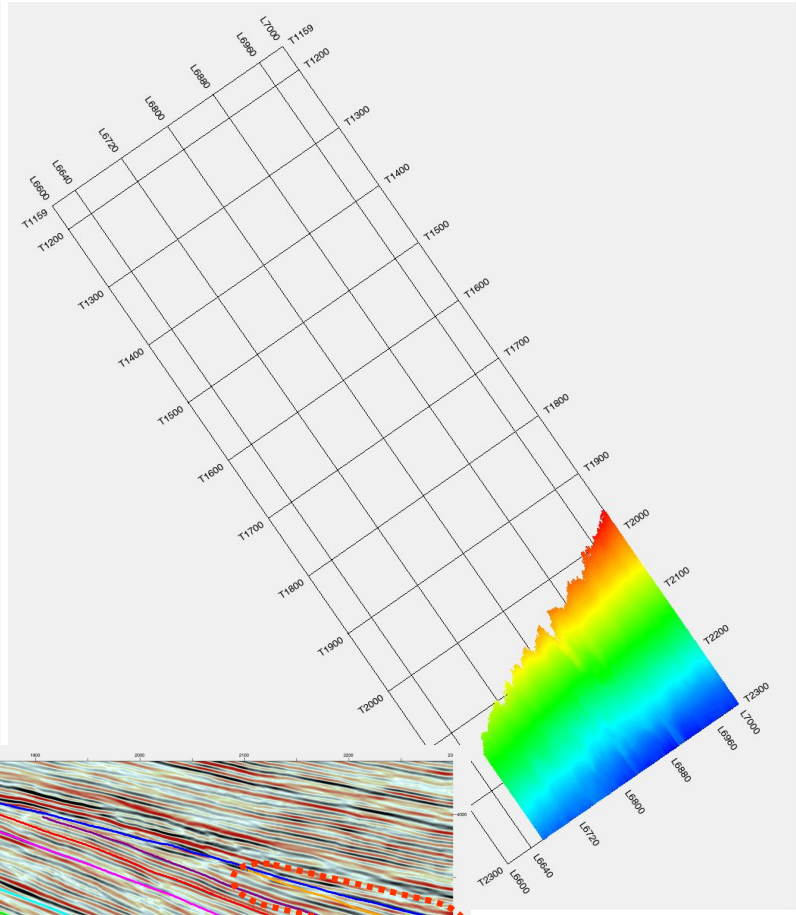
不同标签解释密度预测结果对比

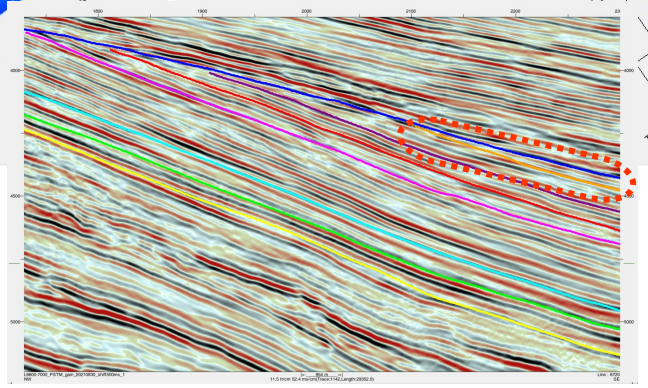


128x128



64x64

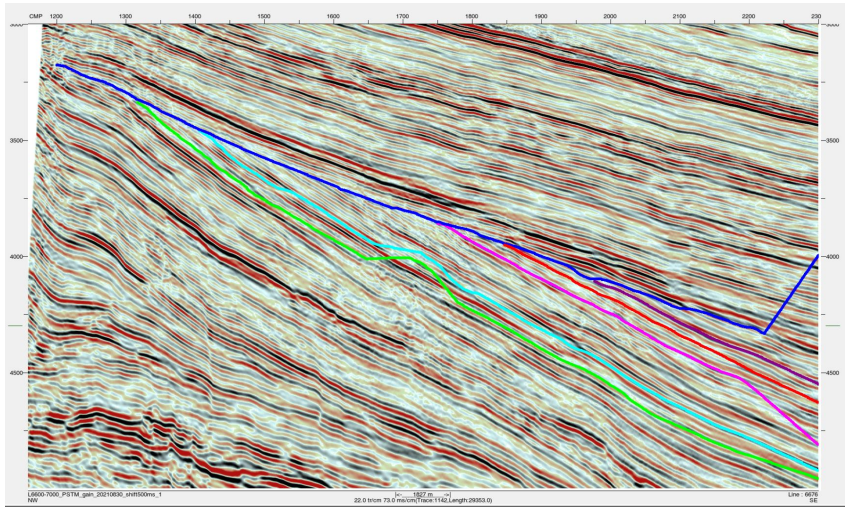




32x32

参数影响

不同标签解释密度预测结果对比



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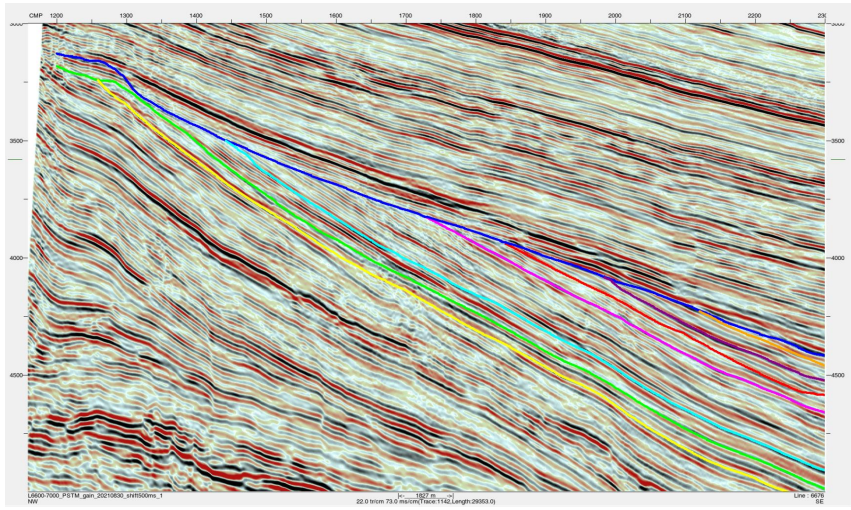

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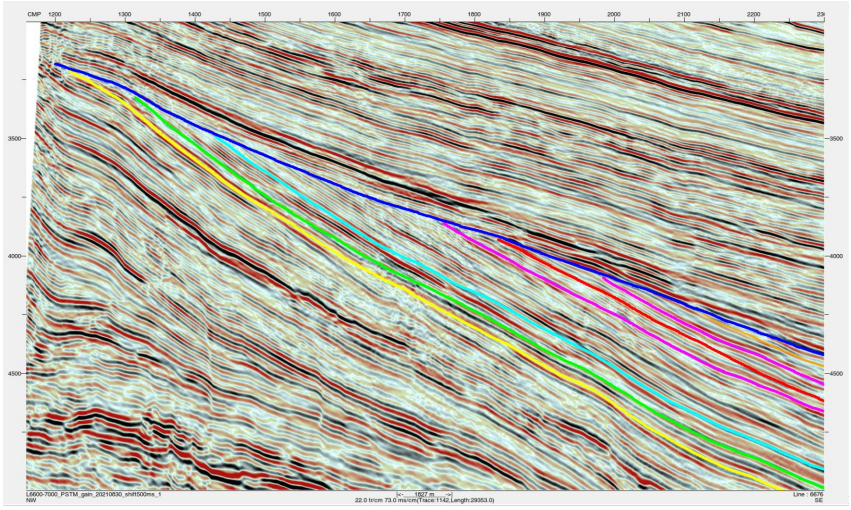
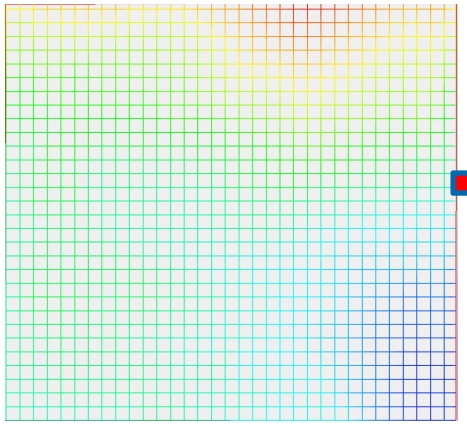


32x32

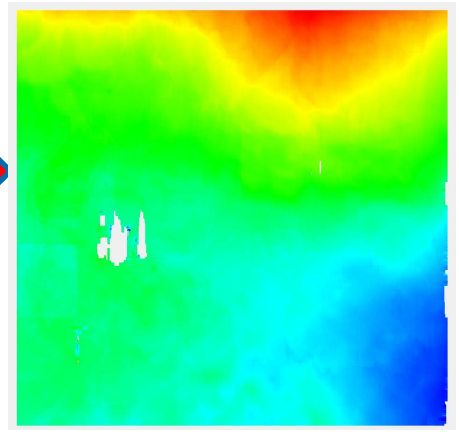
参数影响

显卡对预测结果的影响

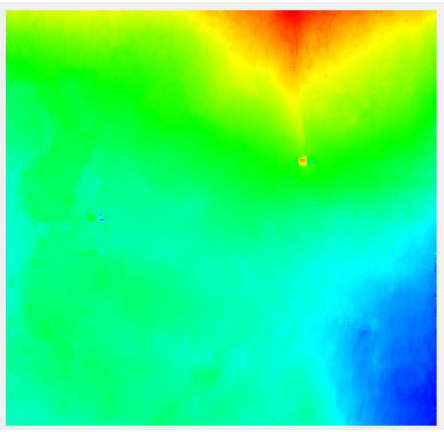
骨架层位128x128



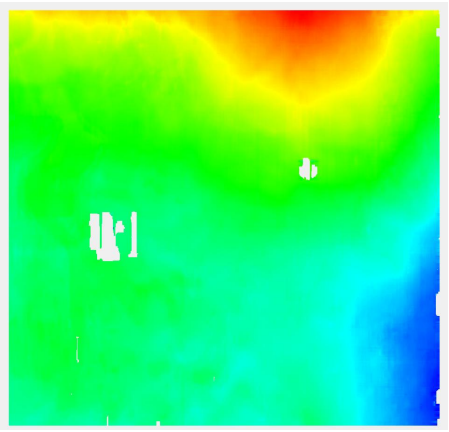
TZ2q



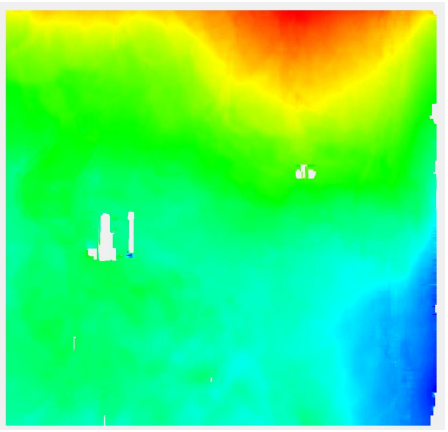
TH1x



TH1w

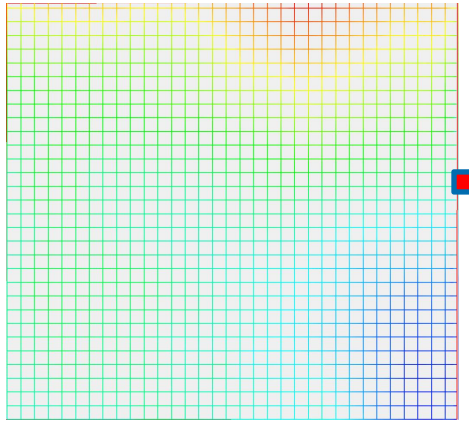


TH2s



浪潮

骨架层位128x128



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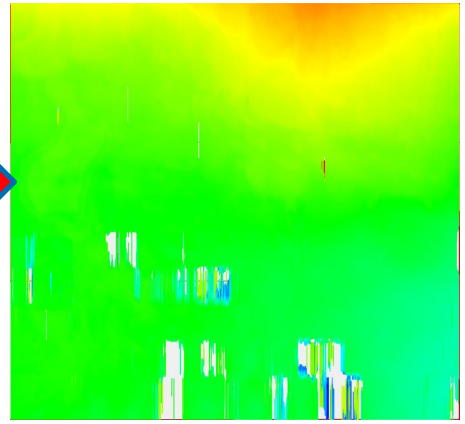
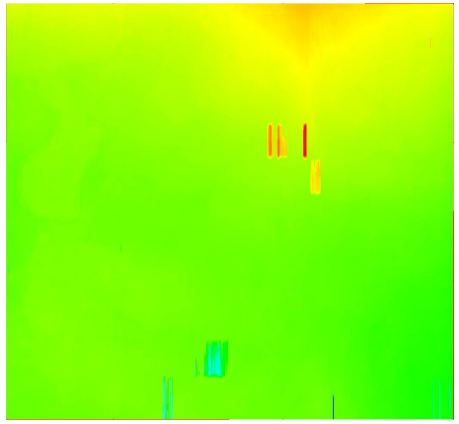
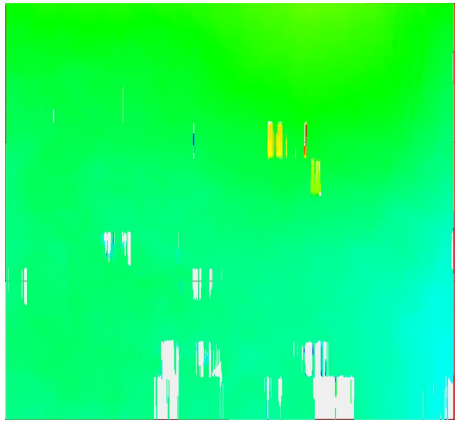


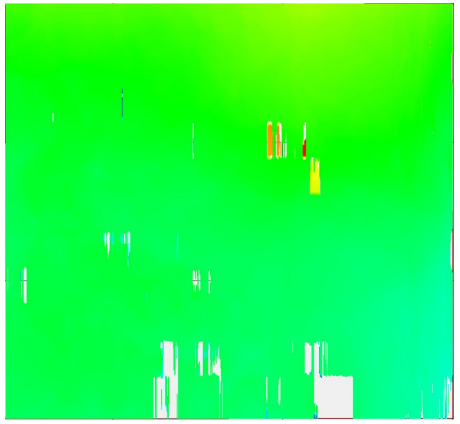
TO12y2



TH1w



TH2s



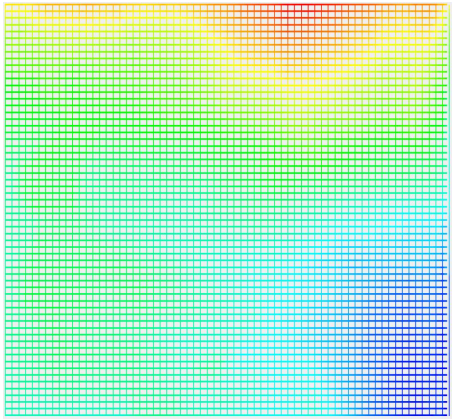
华为2

参数影响

显卡对预测结果的影响

预测范围10000km²

骨架层位64x64



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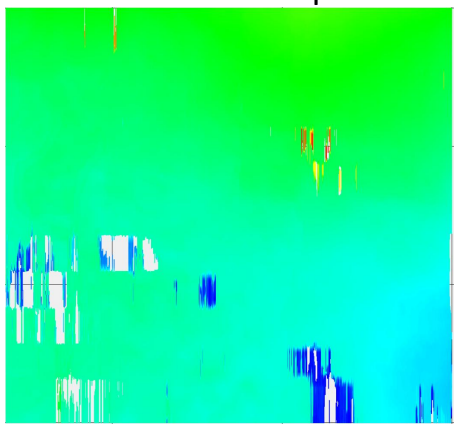
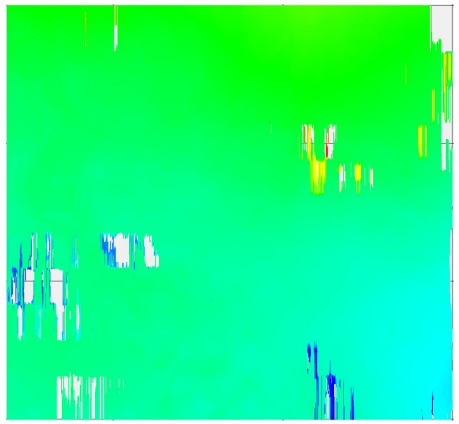
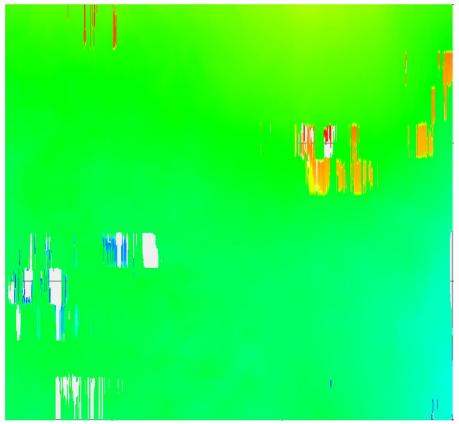


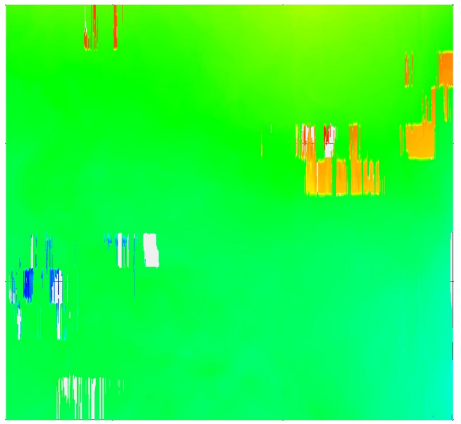
TH1x



TH1w

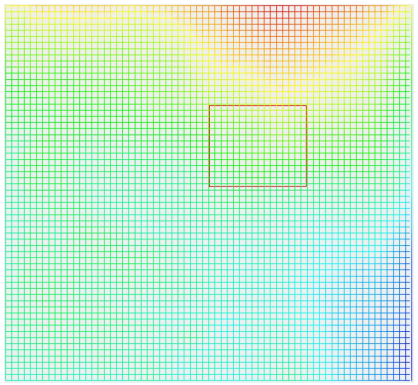


TH2s

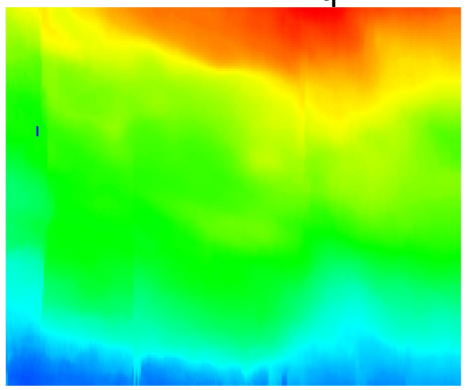


预测范围500km²

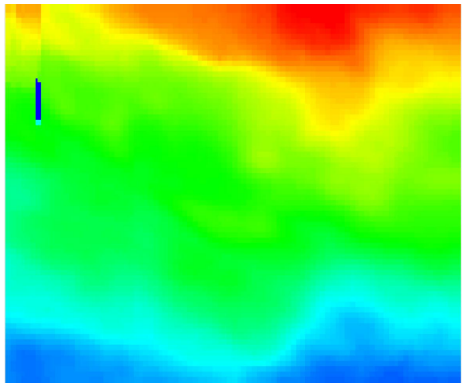
骨架层位64x64



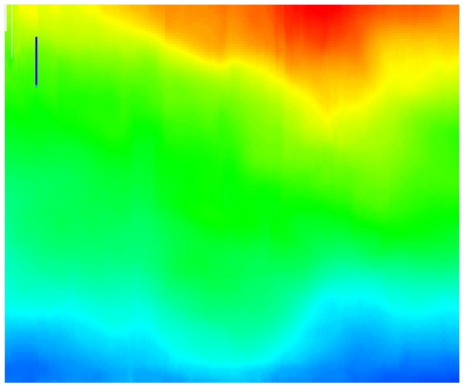
TZ2q



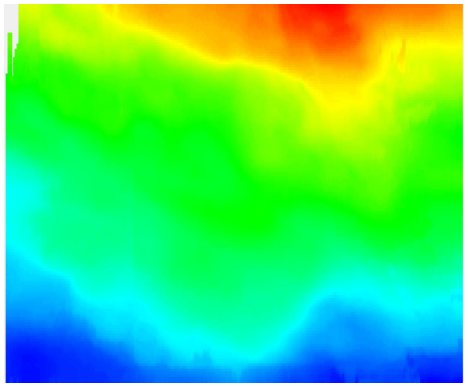
TH1x



TH1w



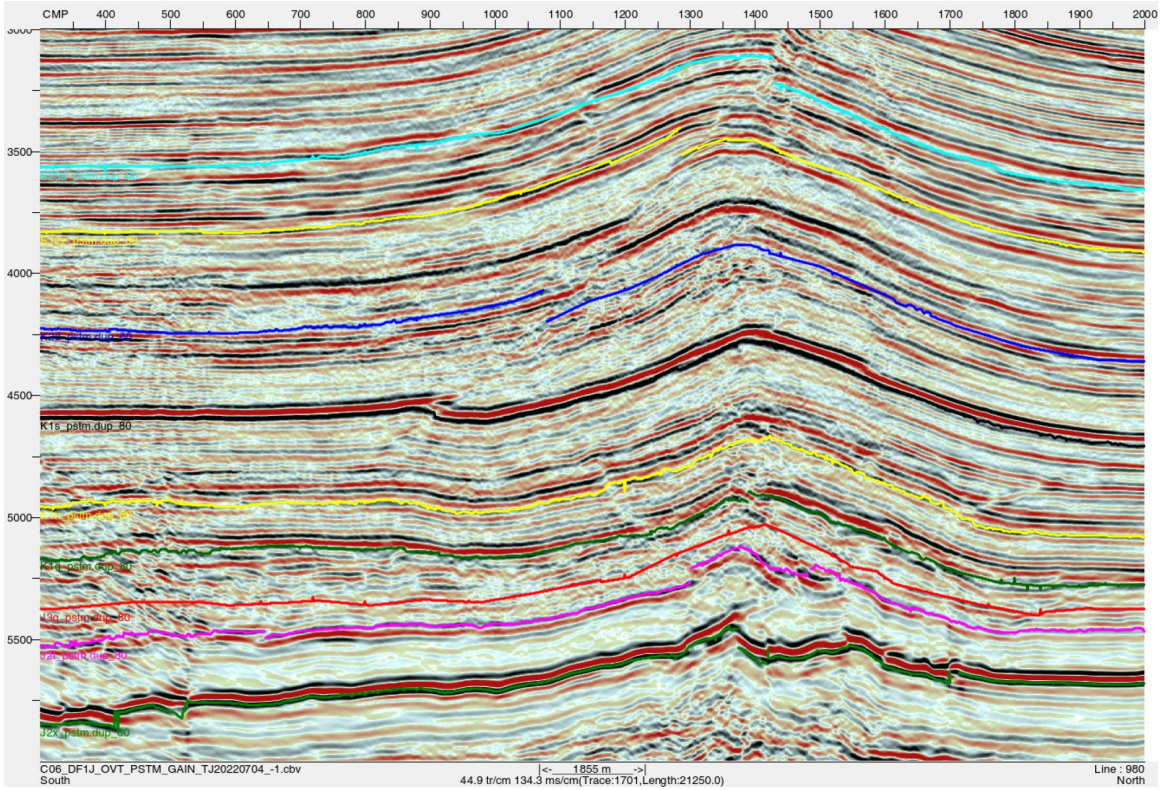
TH2s



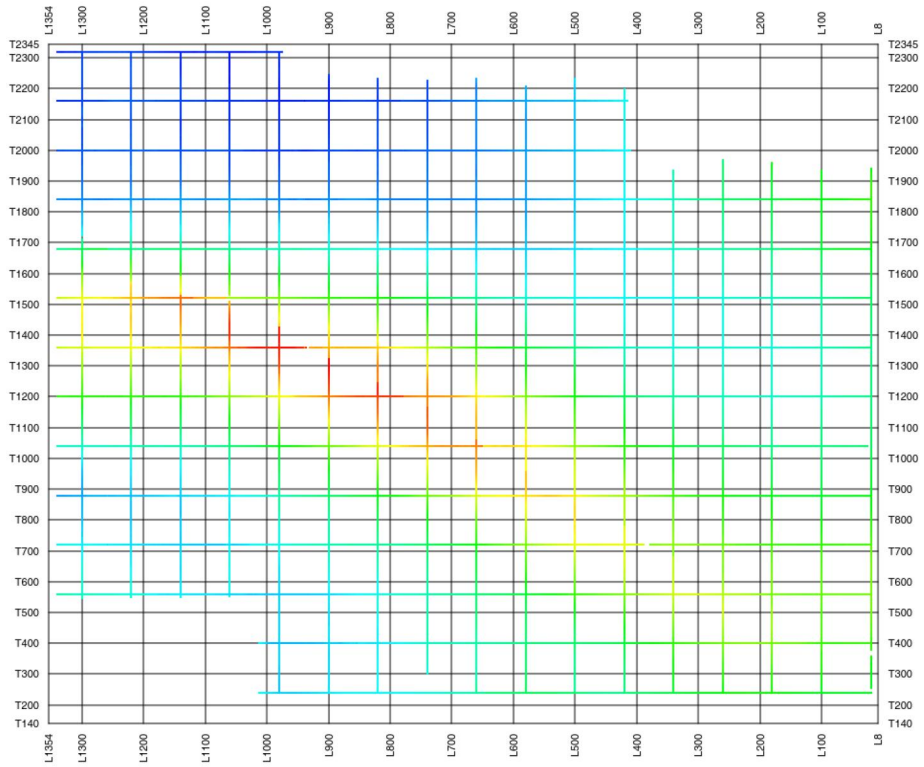
CONTENES
目录

应用案例

案例1：西部某工区共计900km²，解释间隔80X80，选取Inline方向选取17个剖面(1.26%)作为标签，Xline方向14个剖面(0.6%)作为标签，9个层位同步追踪。

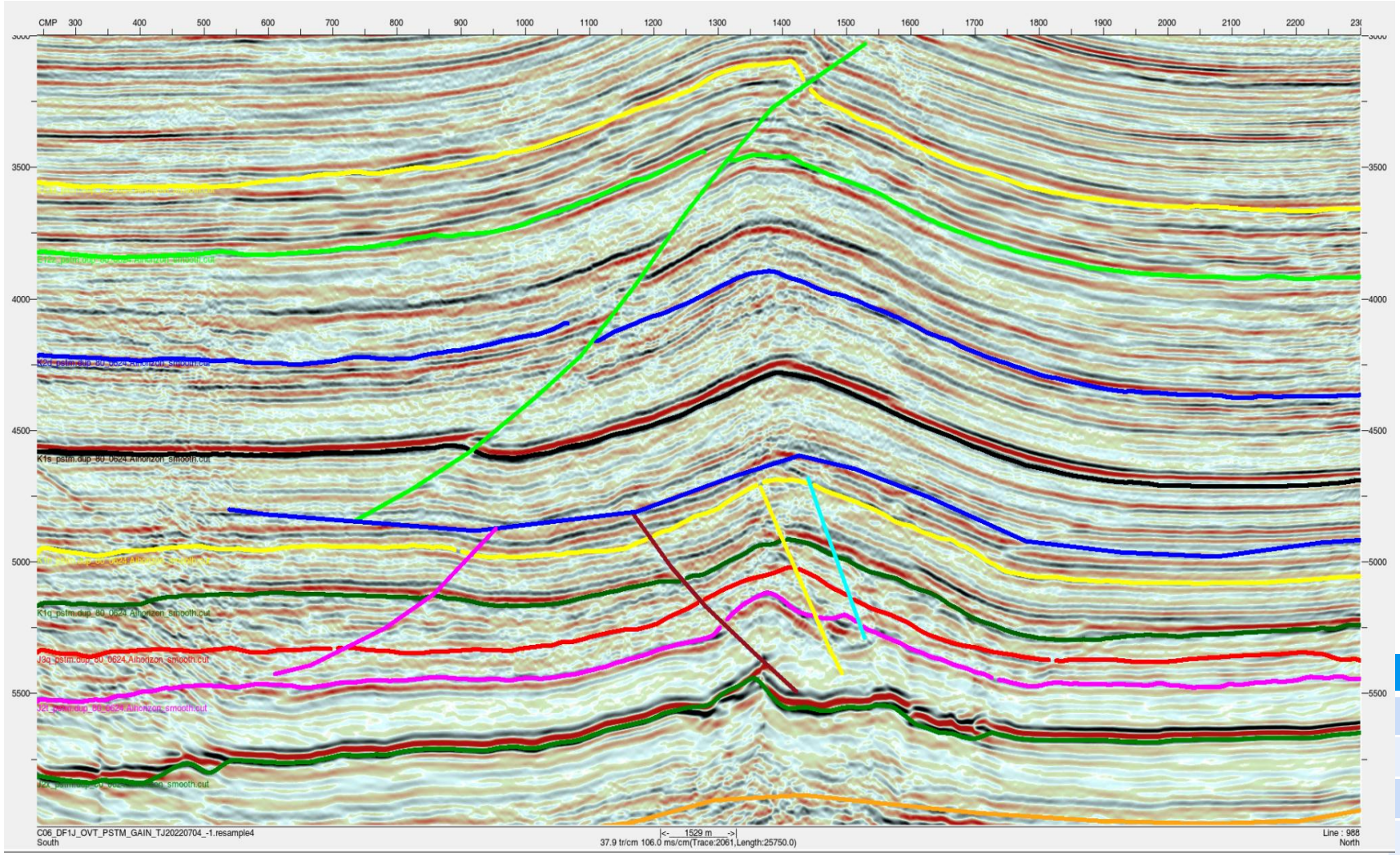


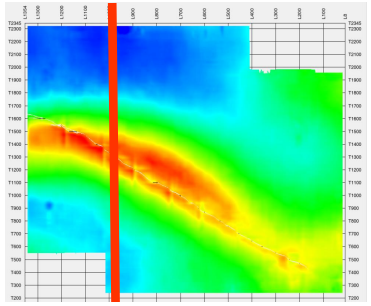
层位inline方向的标签



E23a层位搁架

应用案例



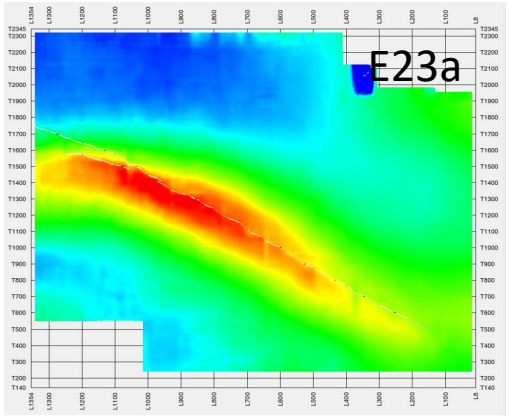


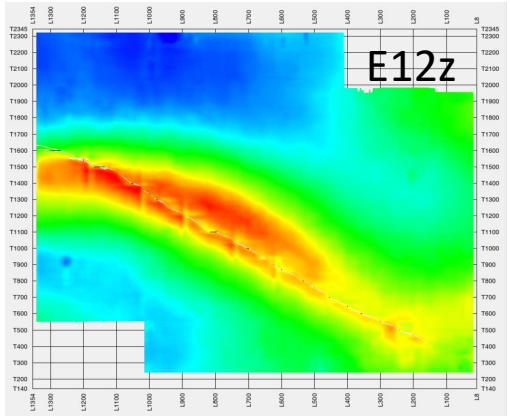
流程	时间
读写数据	21 min
标签制作	17 min
标签训练	415 min
层位预测	87 min

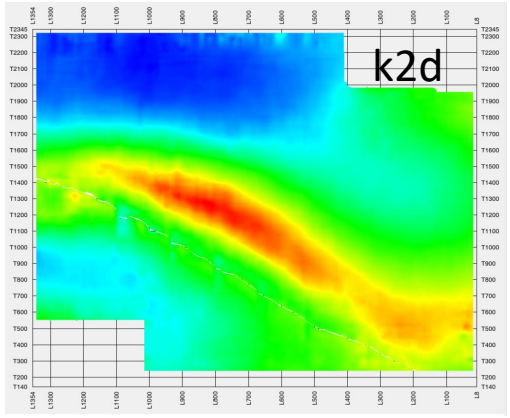
准格尔盆地某工区930km²，1346条主测线，2205条联络测线，间隔80线，解释17条骨架剖面作为标签，9小时完成9套层位解释。（英伟达A100）

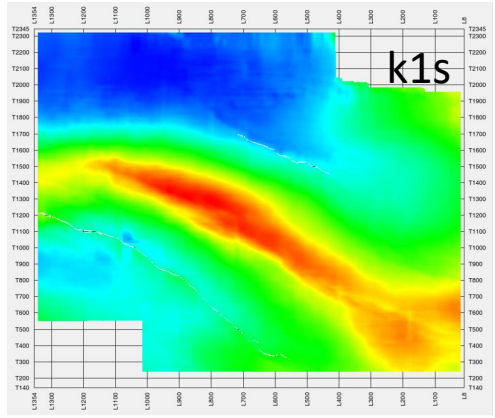
应用案例

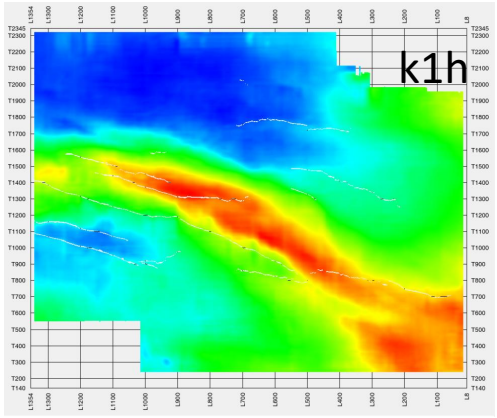
平面预测结果:

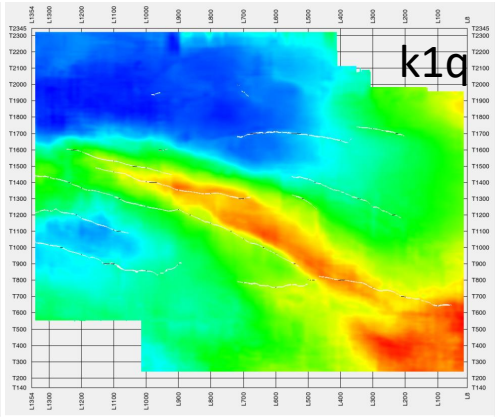


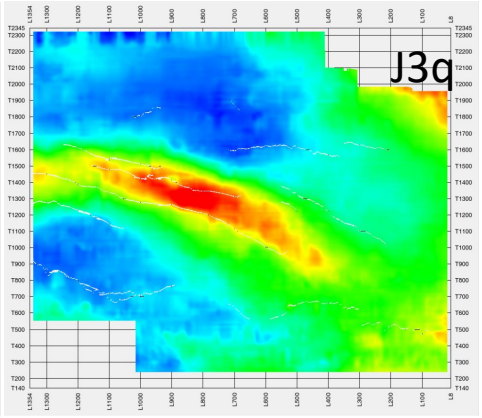


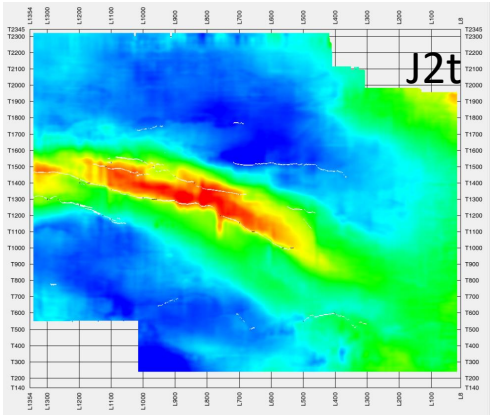


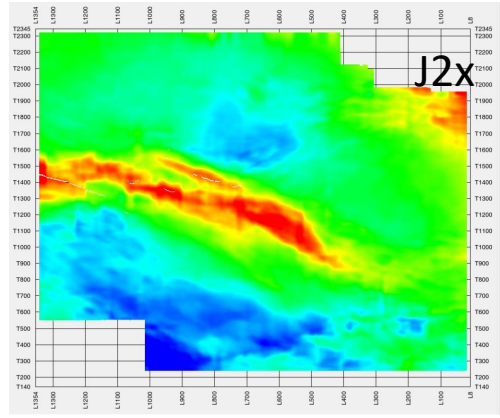






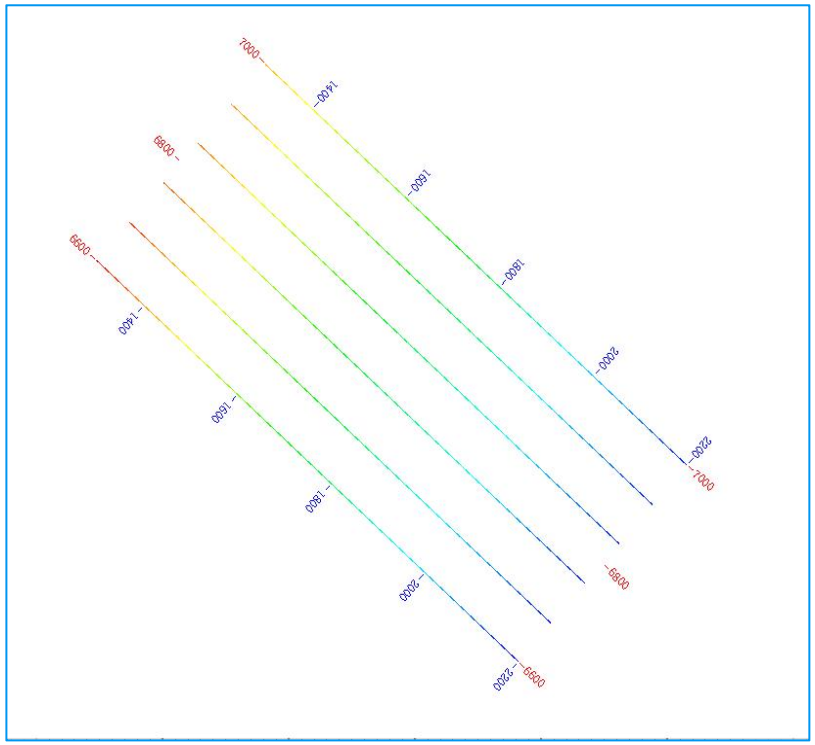




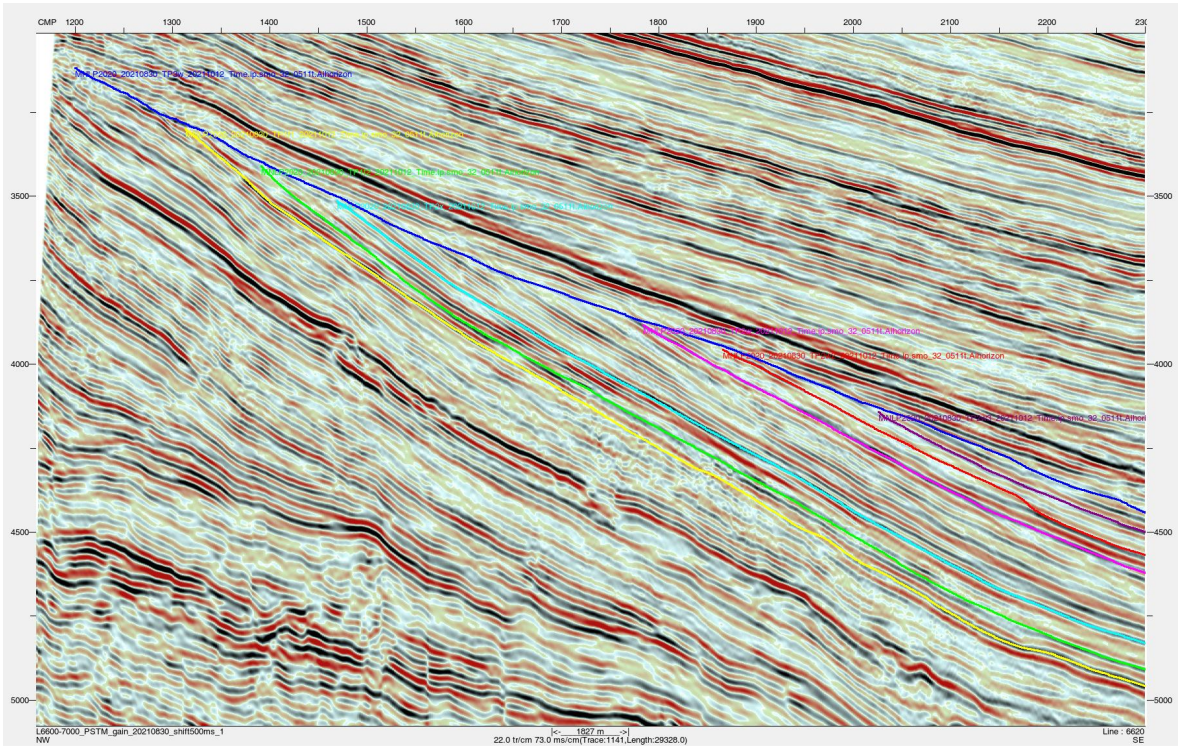


应用案例

案例2：某斜坡数据低信噪比地区测试工区，Inline方向选取6个剖面作为标签，7个层位同步追踪



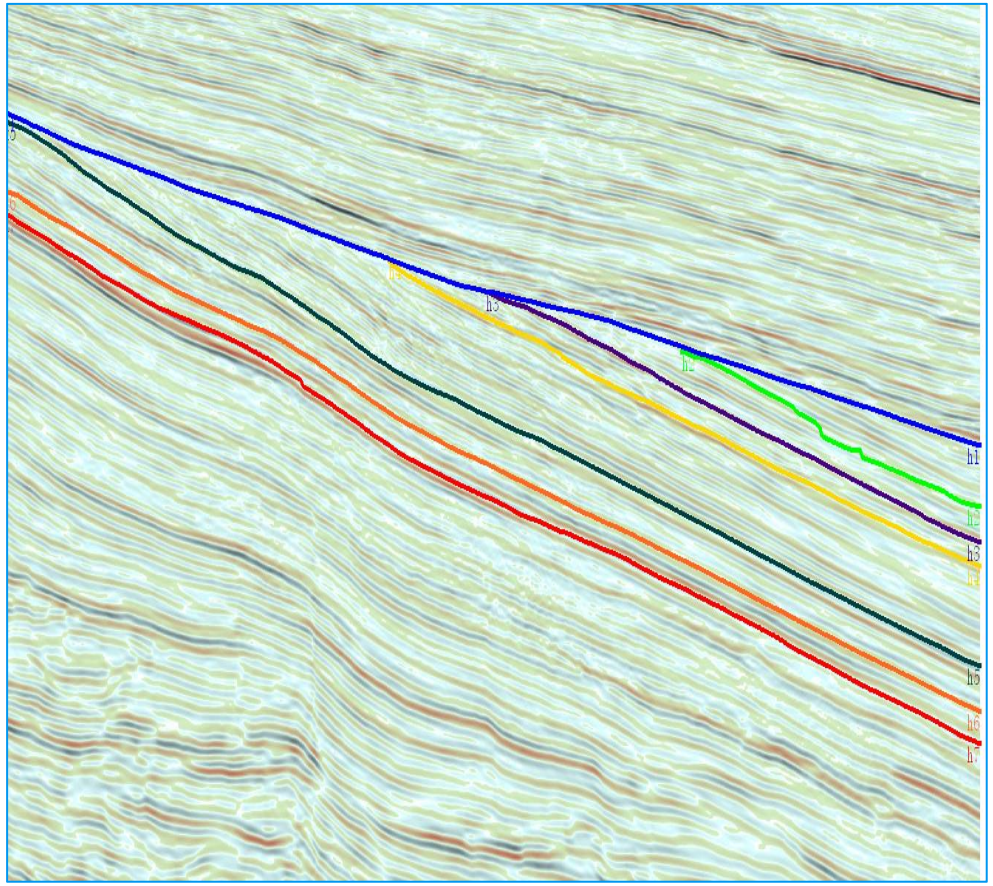
H1层位inline标签



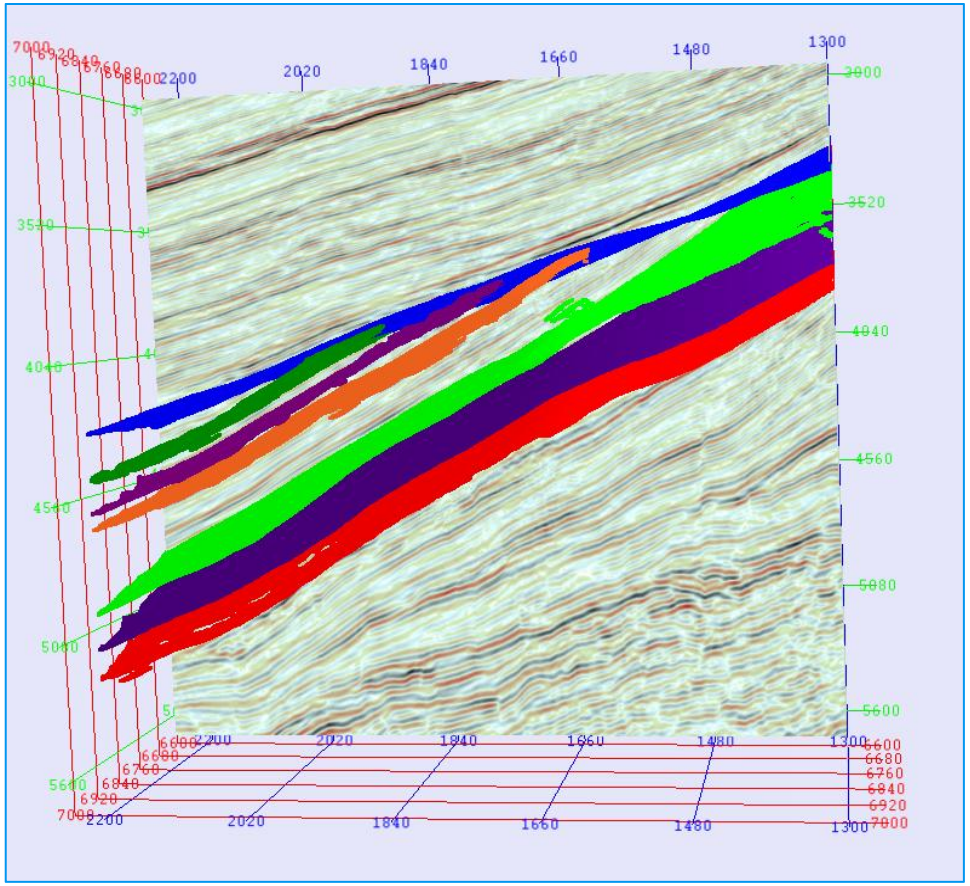
剖面inline标签

应用案例

智能多层位自动拾取模块拾取的7个层位



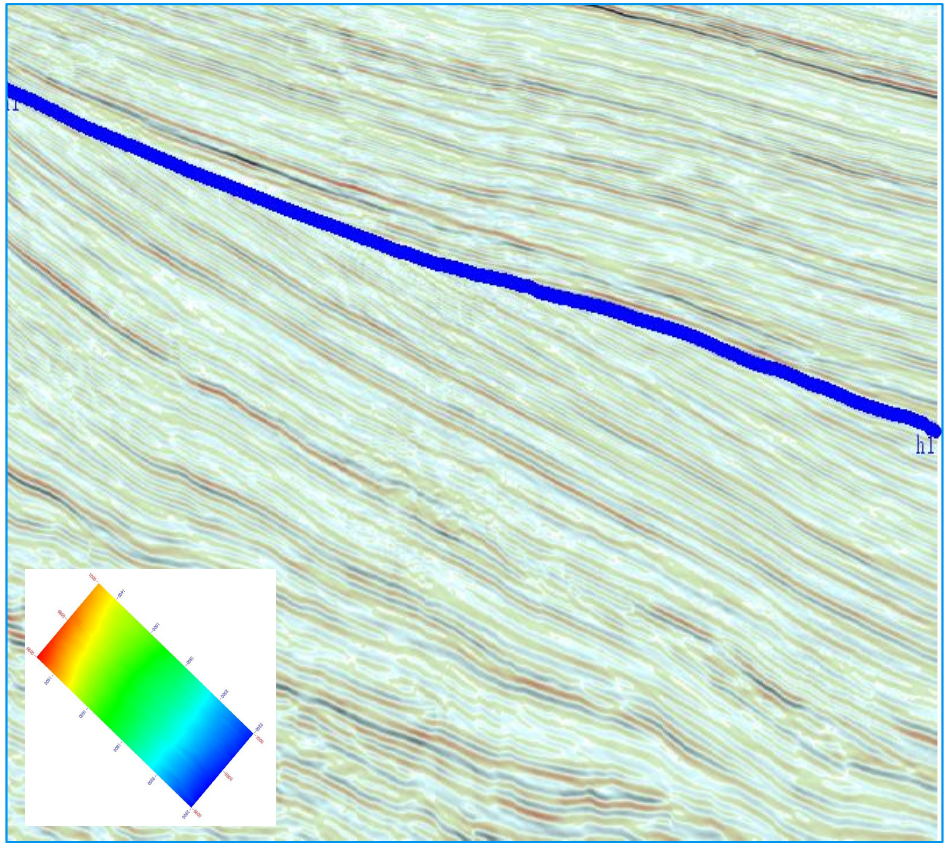
Inline 6810



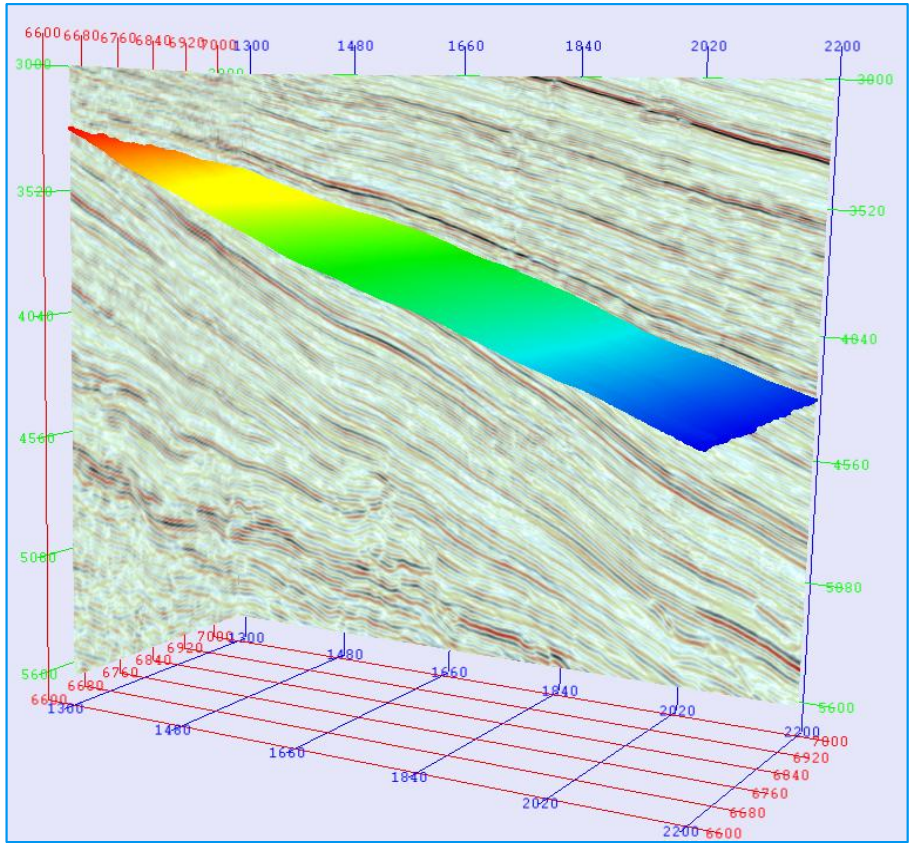
3D 可视化显示

应用案例

智能多层位算法H1层位拾取结果



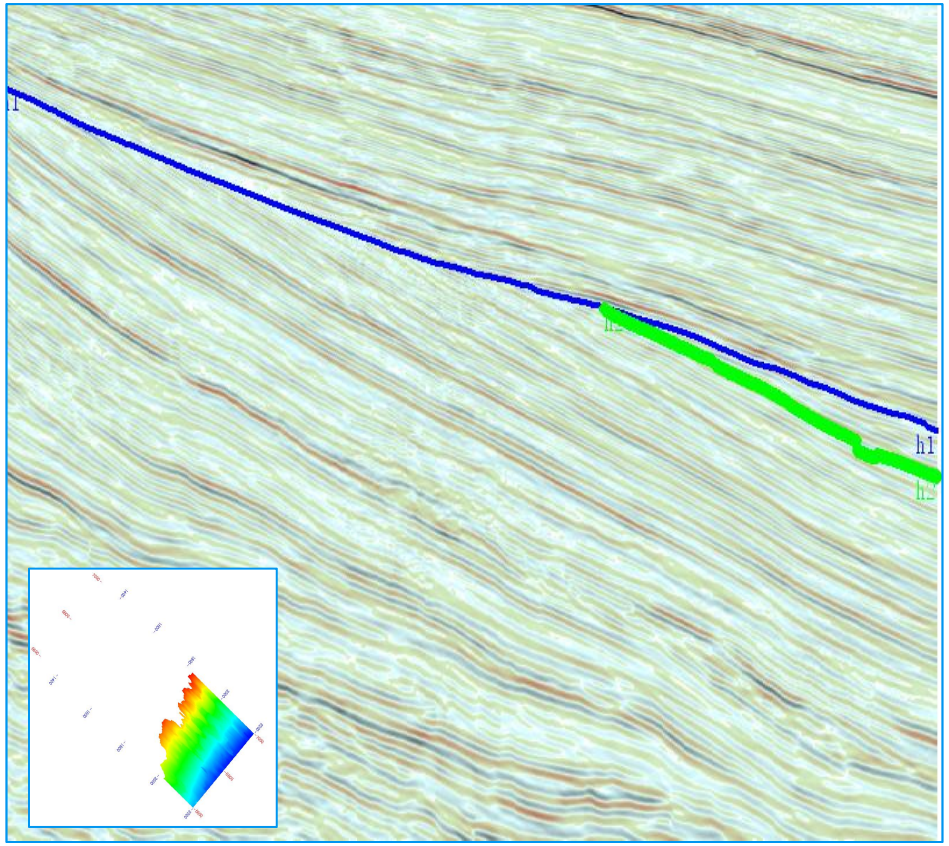
inline 6780



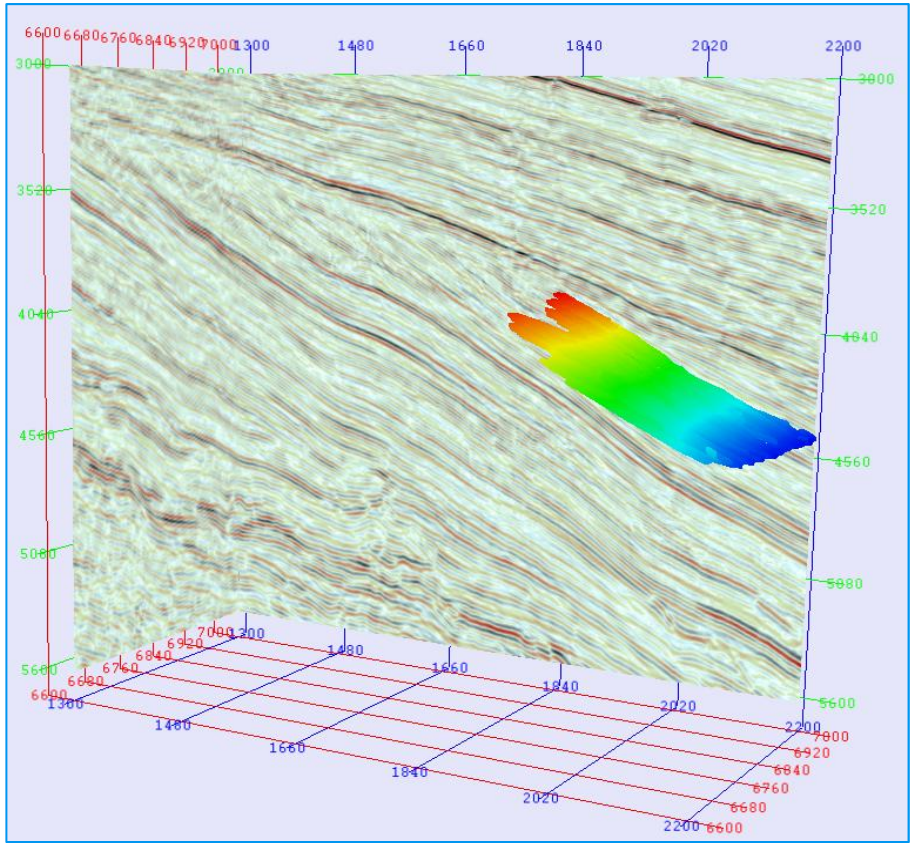
3D显示

应用案例

智能多层位算法H2层位拾取结果



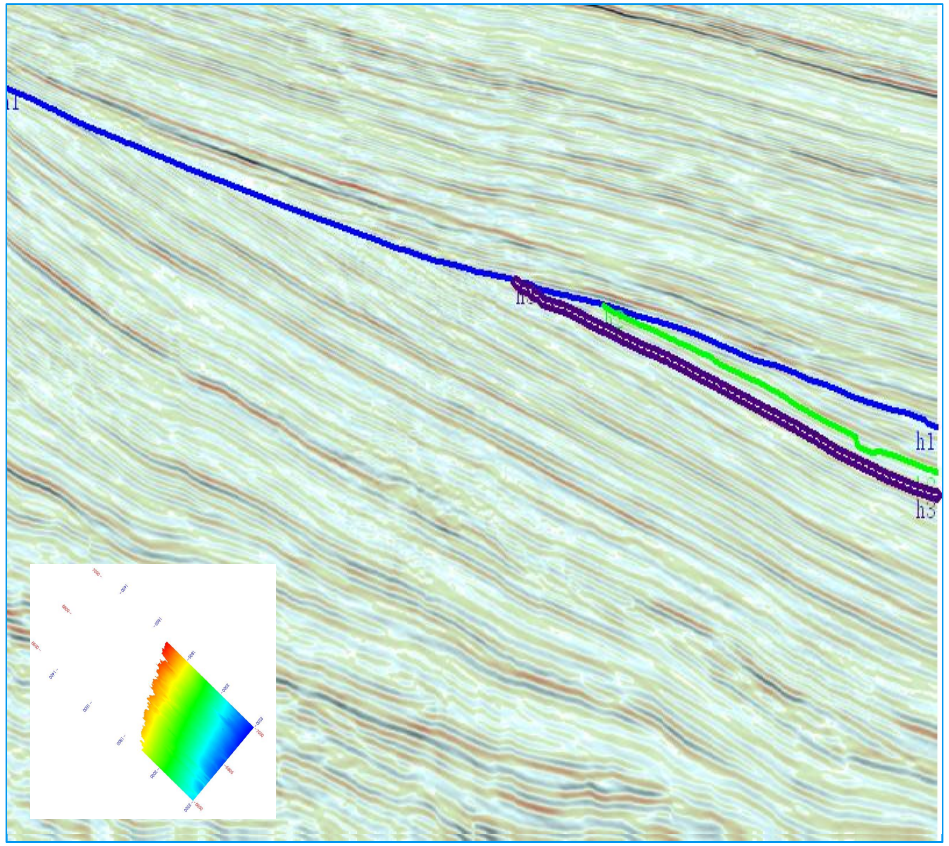
inline 6780



3D显示

应用案例

智能多层位算法H3层位拾取结果



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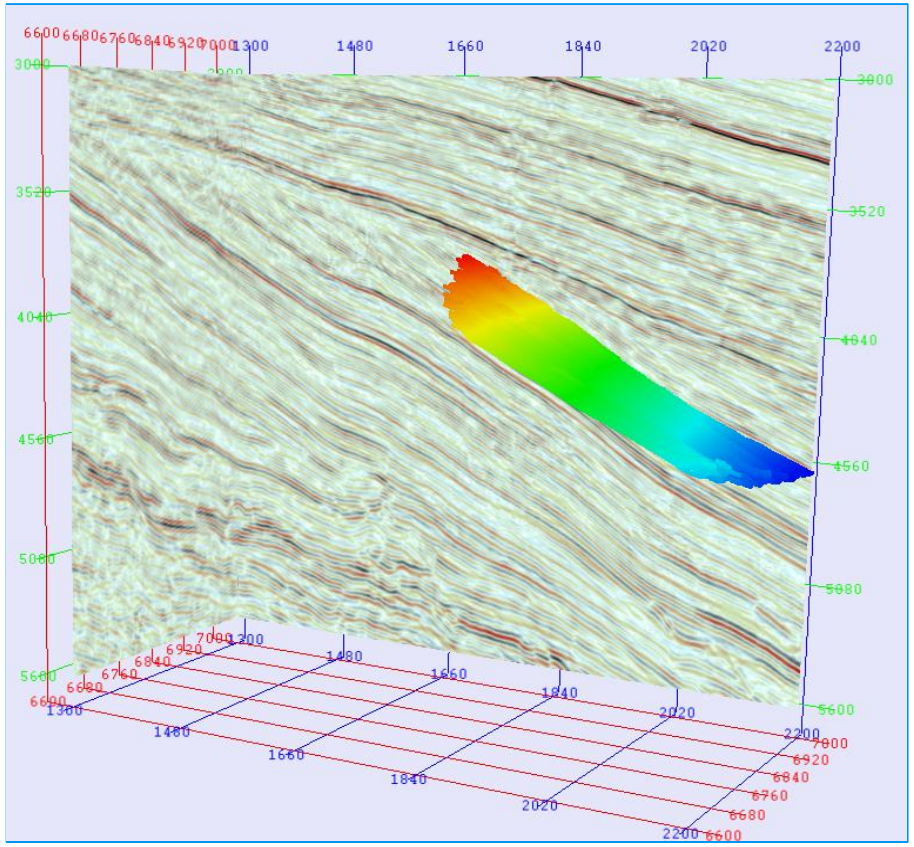
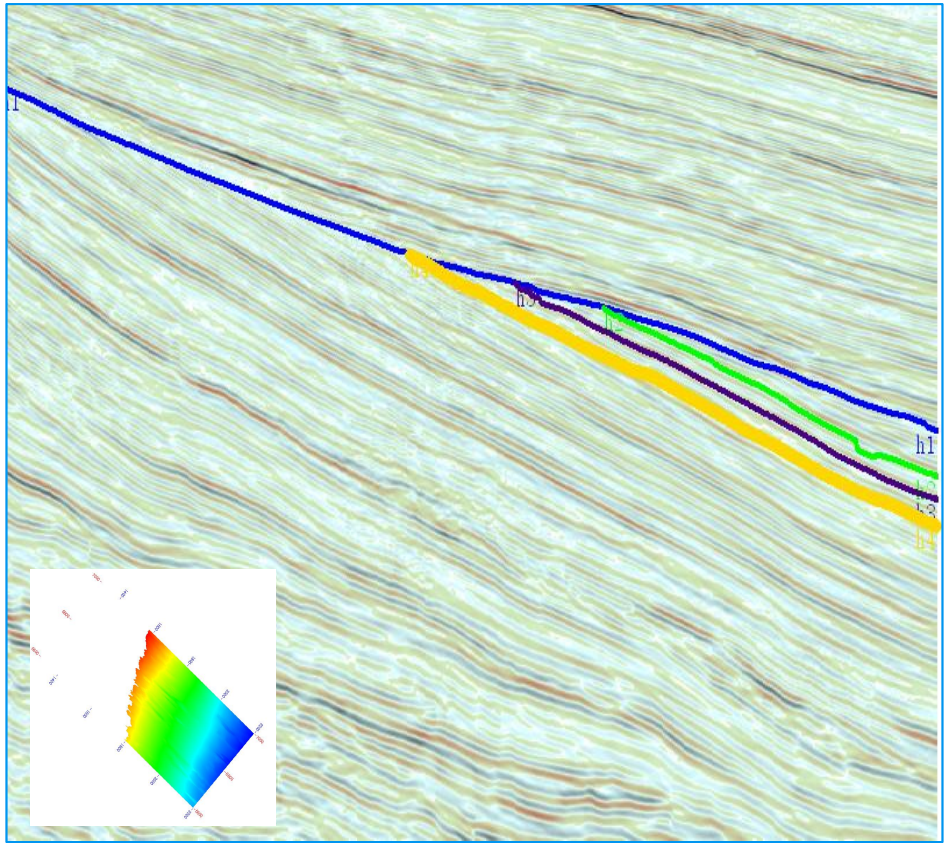


3D显示

应用案例

智能多层位算法H4层位拾取结果



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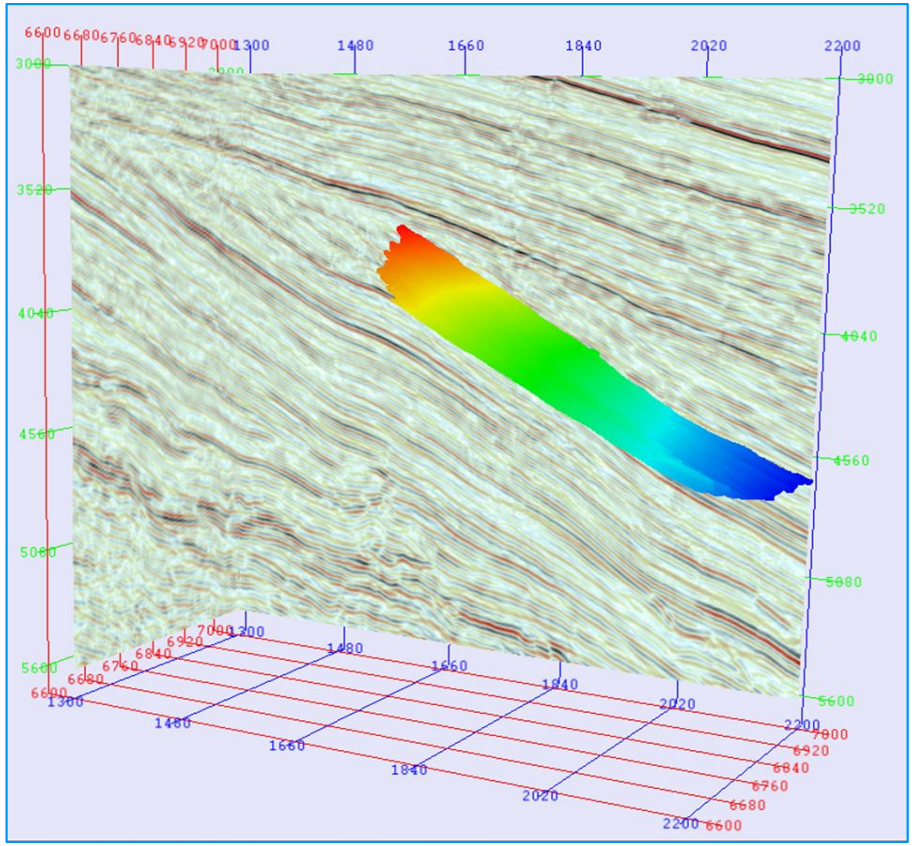
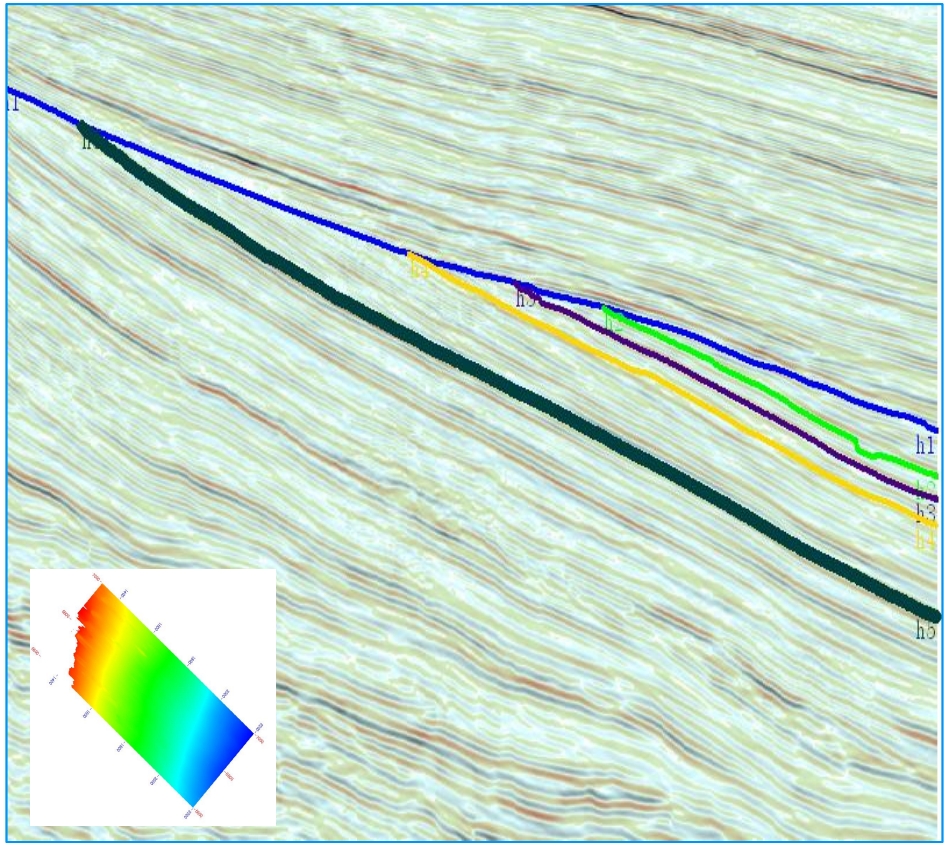


3D显示

应用案例

智能多层位算法H5层位拾取结果



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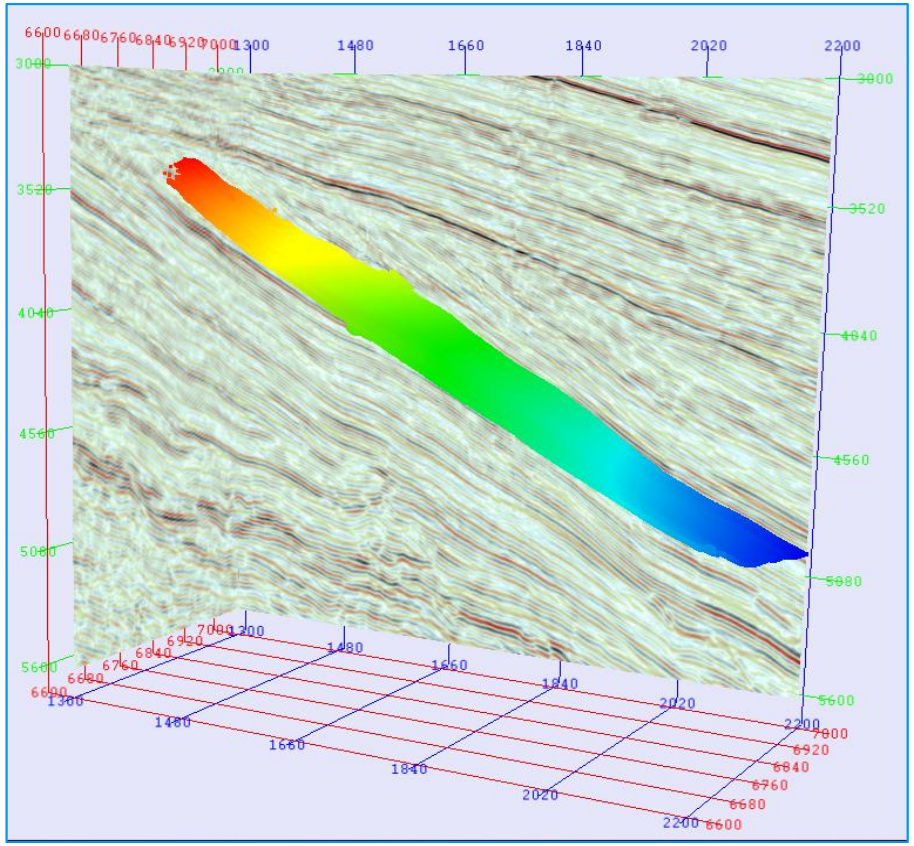
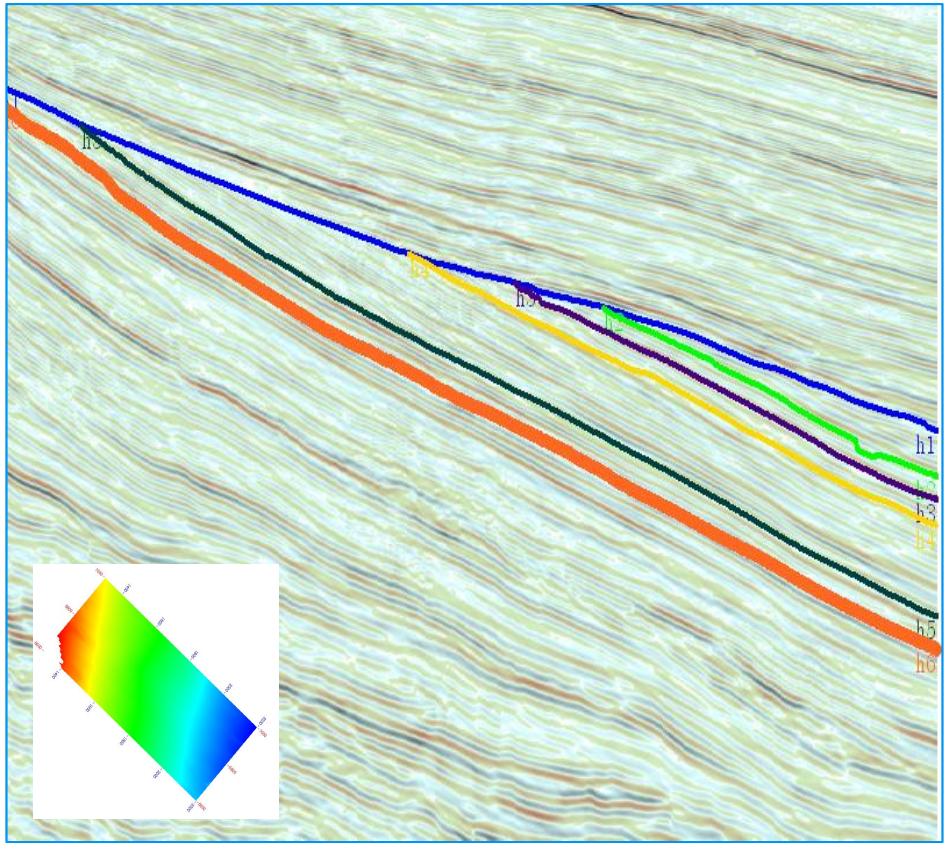


3D显示

应用案例

智能多层位算法H6层位拾取结果



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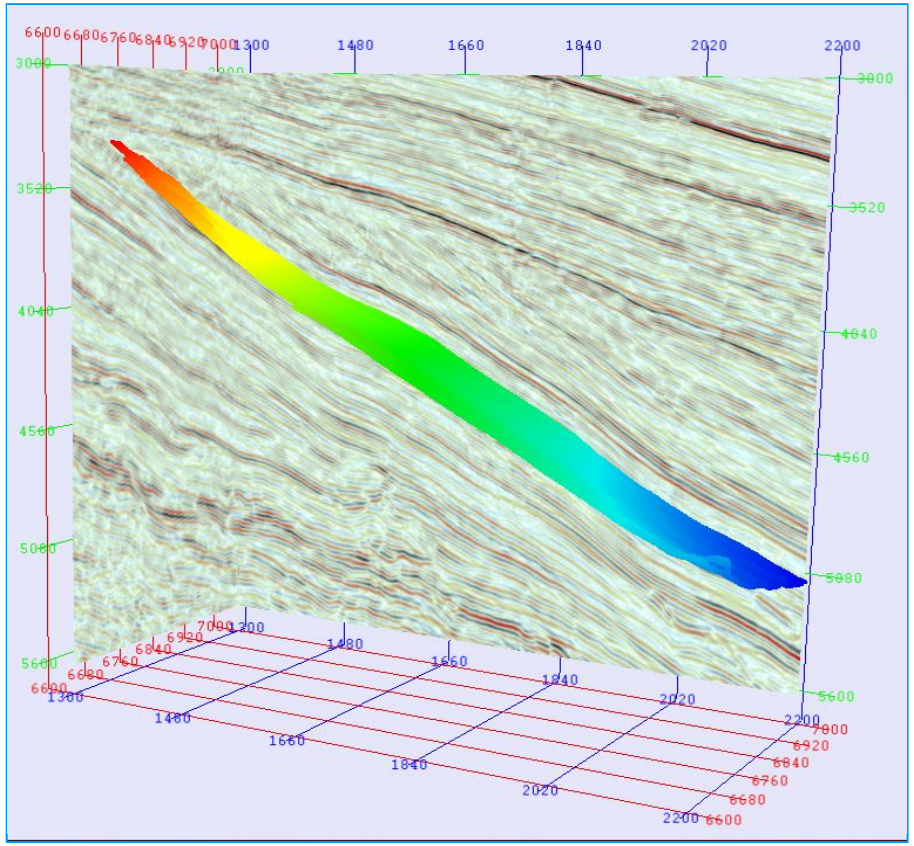
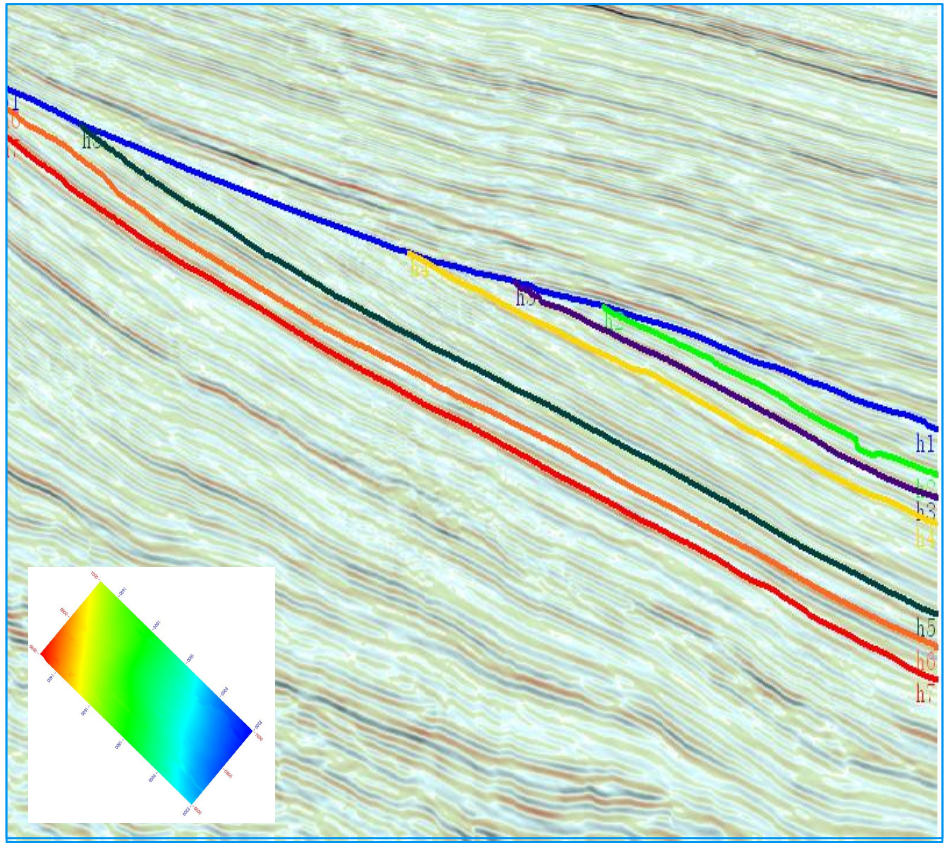


3D显示

应用案例

智能多层位算法H7层位拾取结果



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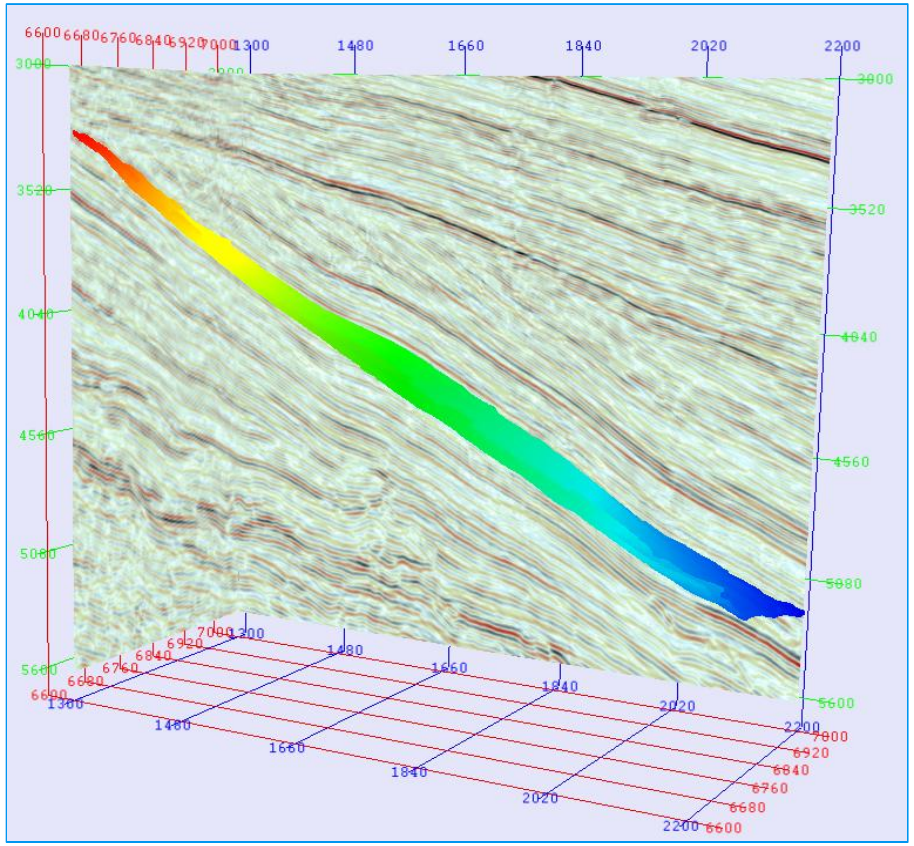

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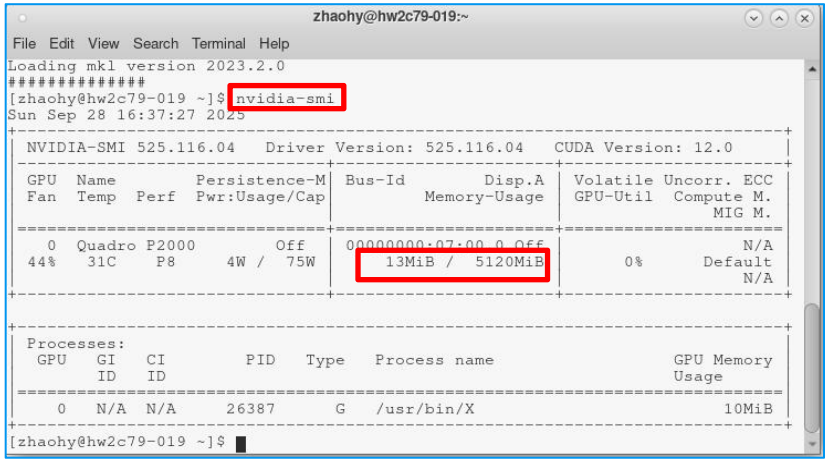
注意事项

1、首先用nvidia-smi命令来看GPU使用情况，**GPU要预留最少4GB的显存**；

2、标签解释剖面上每个层位需要**解释完整**，并且**解释密度保持一致**，不一致时选择最稀疏标签；

3、多个进程同时进行时，需要选择**不同临时路径**，确保选用的路径具有读写权限，并且硬盘空间够用；

4、预测纵向范围在层位最大最小范围基础上进行拓展，否则**程序会报错**；



感谢大家对GeoEast软件的信任和支持！

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