3-D Seismic Reflector Orientations from 2-D Profiles across the Kalgoorlie Greenstone Belt

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Thanks to :

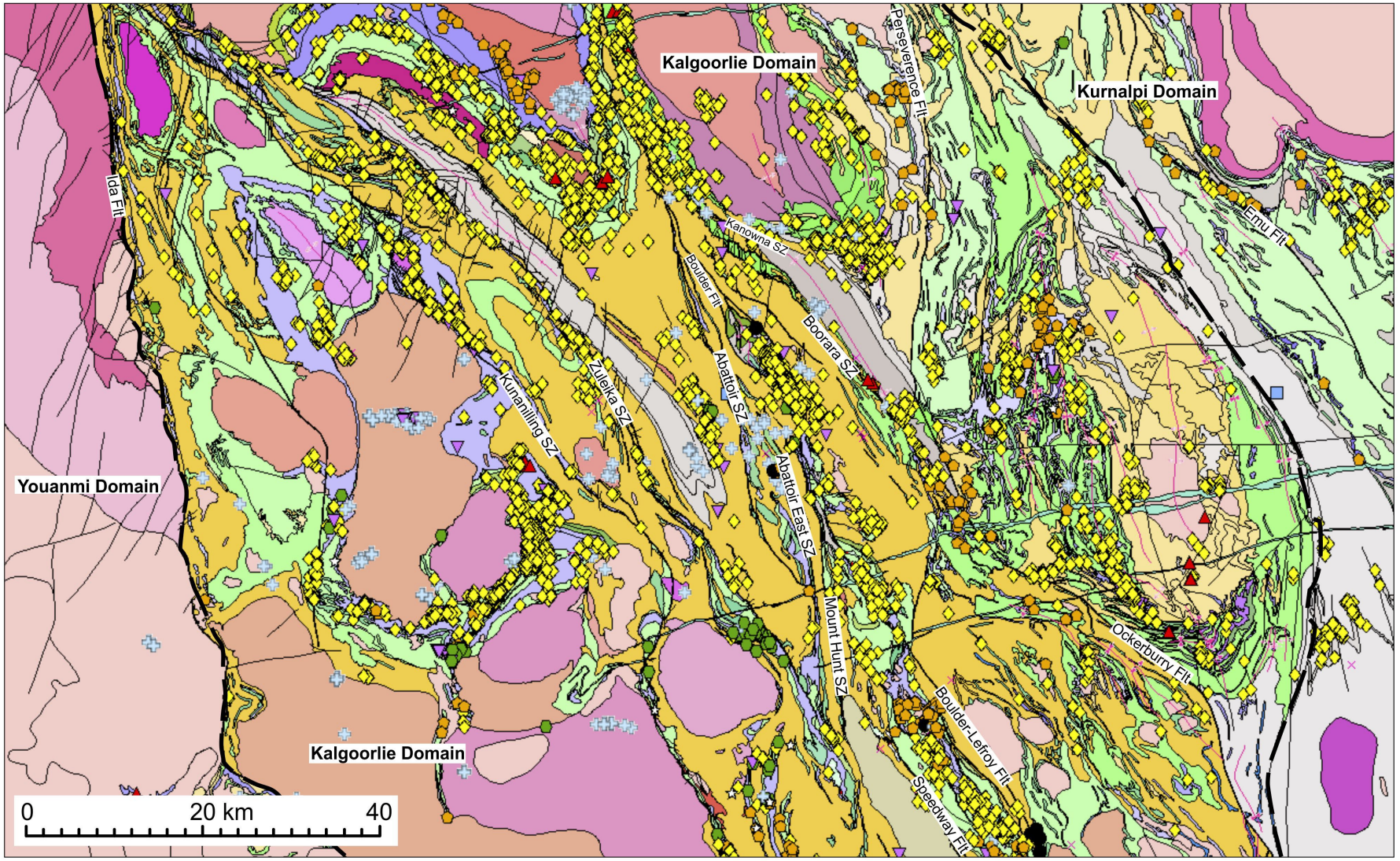
Seismic Acquisition: Geological Survey of Western Australia, Geoscience Australia

Seismic Data Processing: Velseis Pty. Ltd., Tanya Fomin, Ross Costelloe

Geological Background: Jyotindra Sapkota

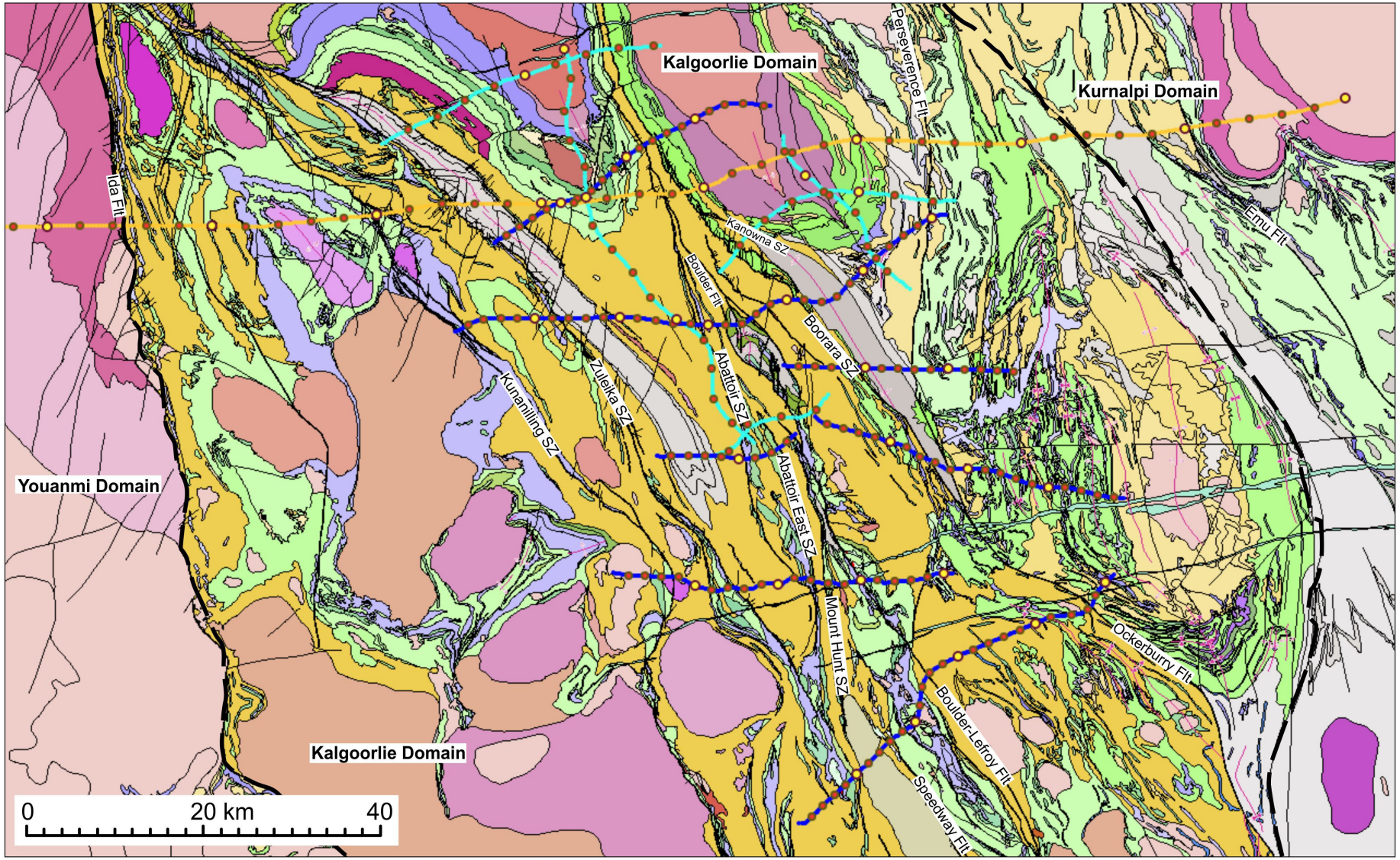
Previous work: Bruce Goleby, Russell Korsch and others

Mineral Deposits of Kalgoorlie Greenstone Belt



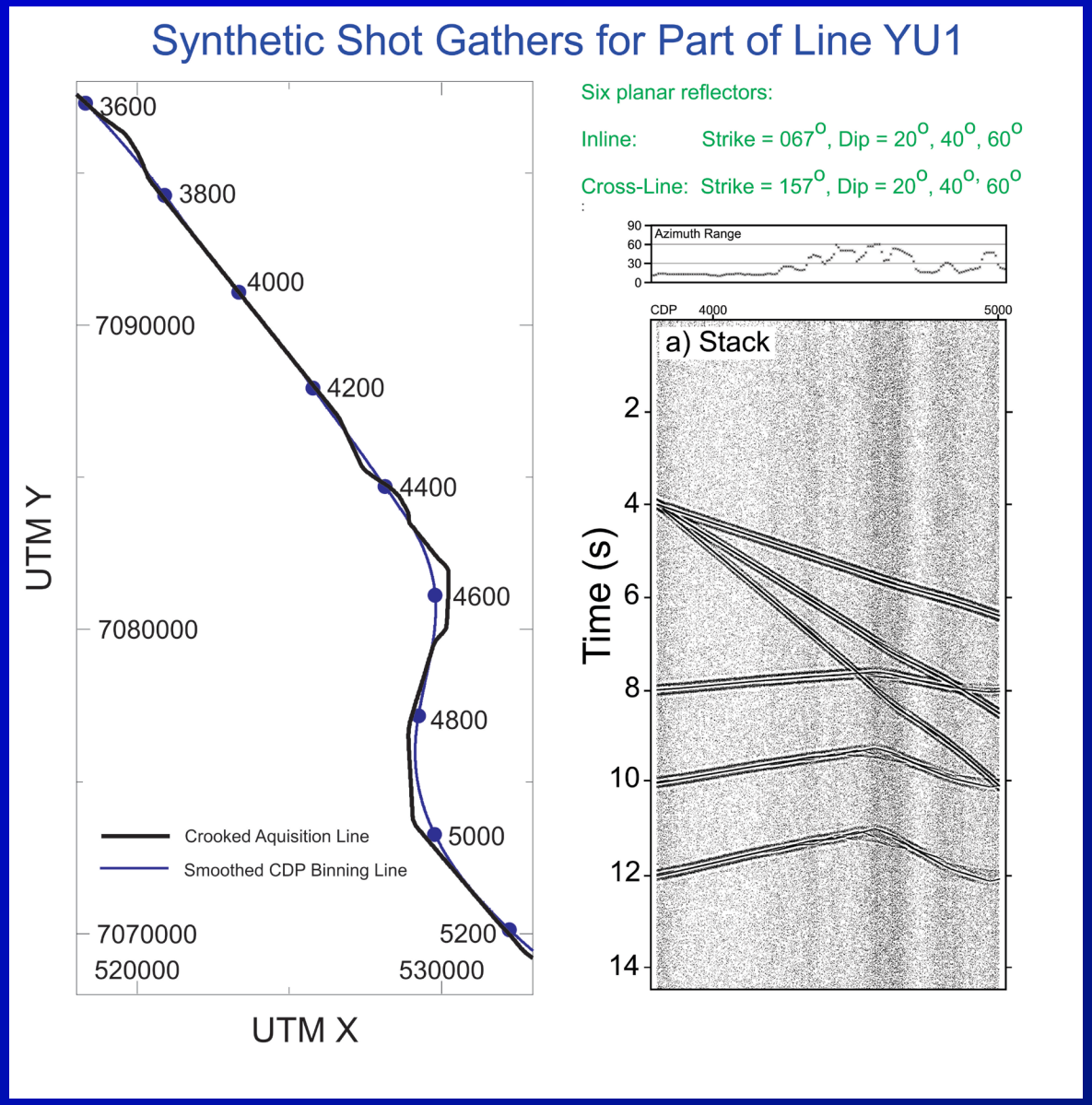
- Large gold and precious metal endowment
- Precious metals mostly found close to mapped fault zones
- Deposits typically associated with volcanic or volcaniclastic rocks
- Highly variable gold endowment along strike

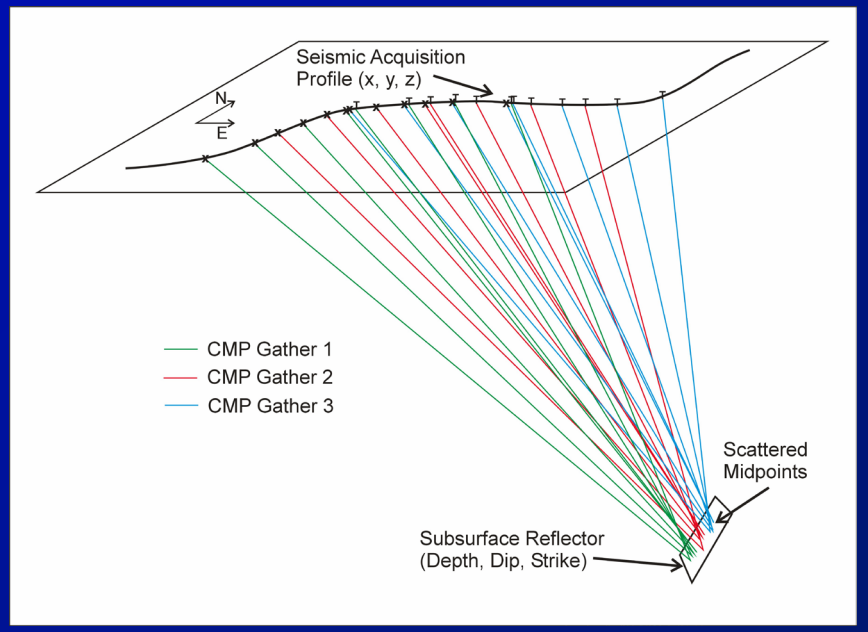
Kalgoorlie Seismic Surveys



- Crooked line surveys for cost-effective acquisiton along existing road access
- Yellow:
  - 1991 - 20 s dynamite
- Cyan:
  - 1999 - 16 s vibroseis
- Blue:
  - 2019 – 5 s or 10 s vibroseis

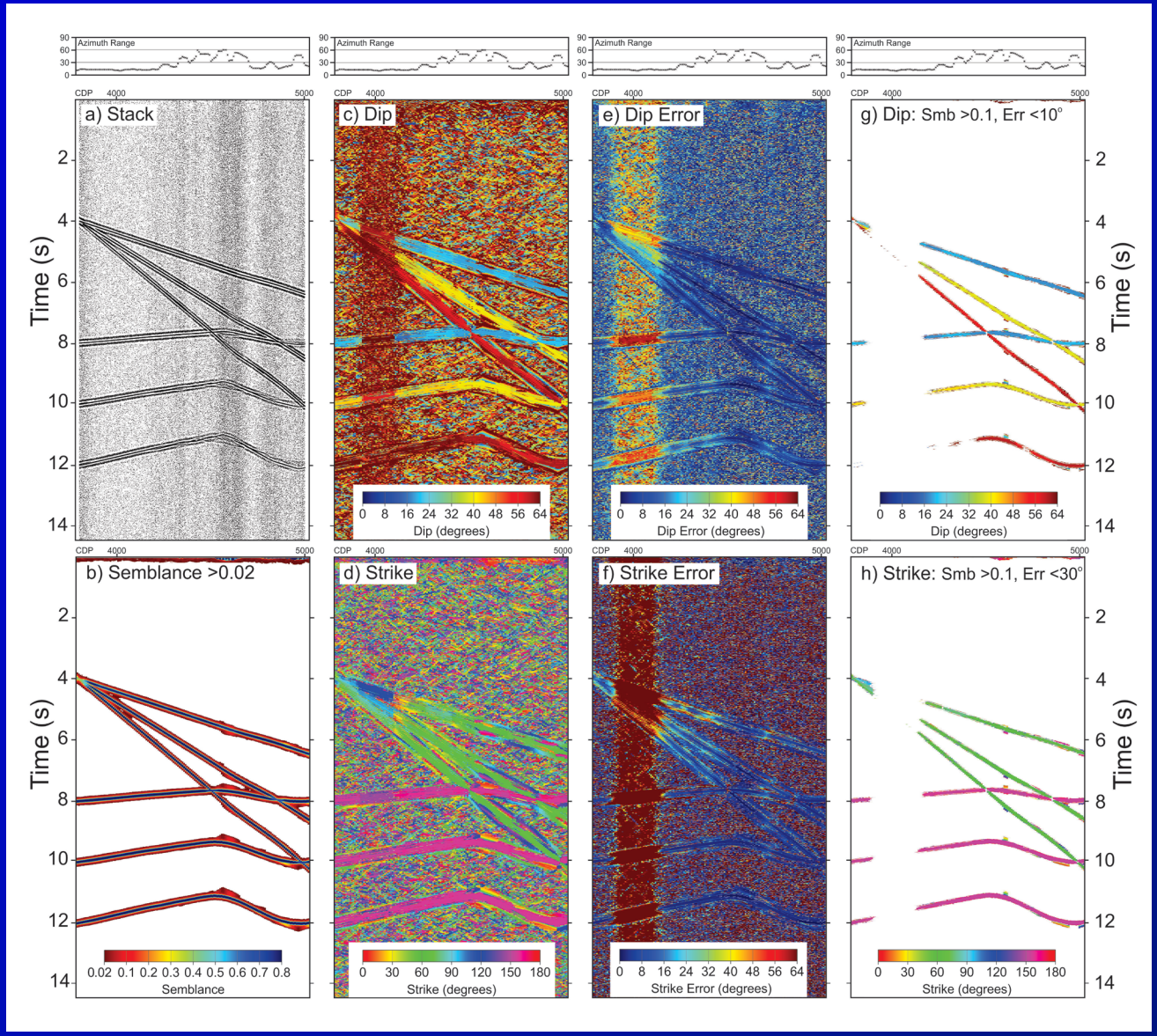
Seismic Reflection Surveys Along Crooked Profiles





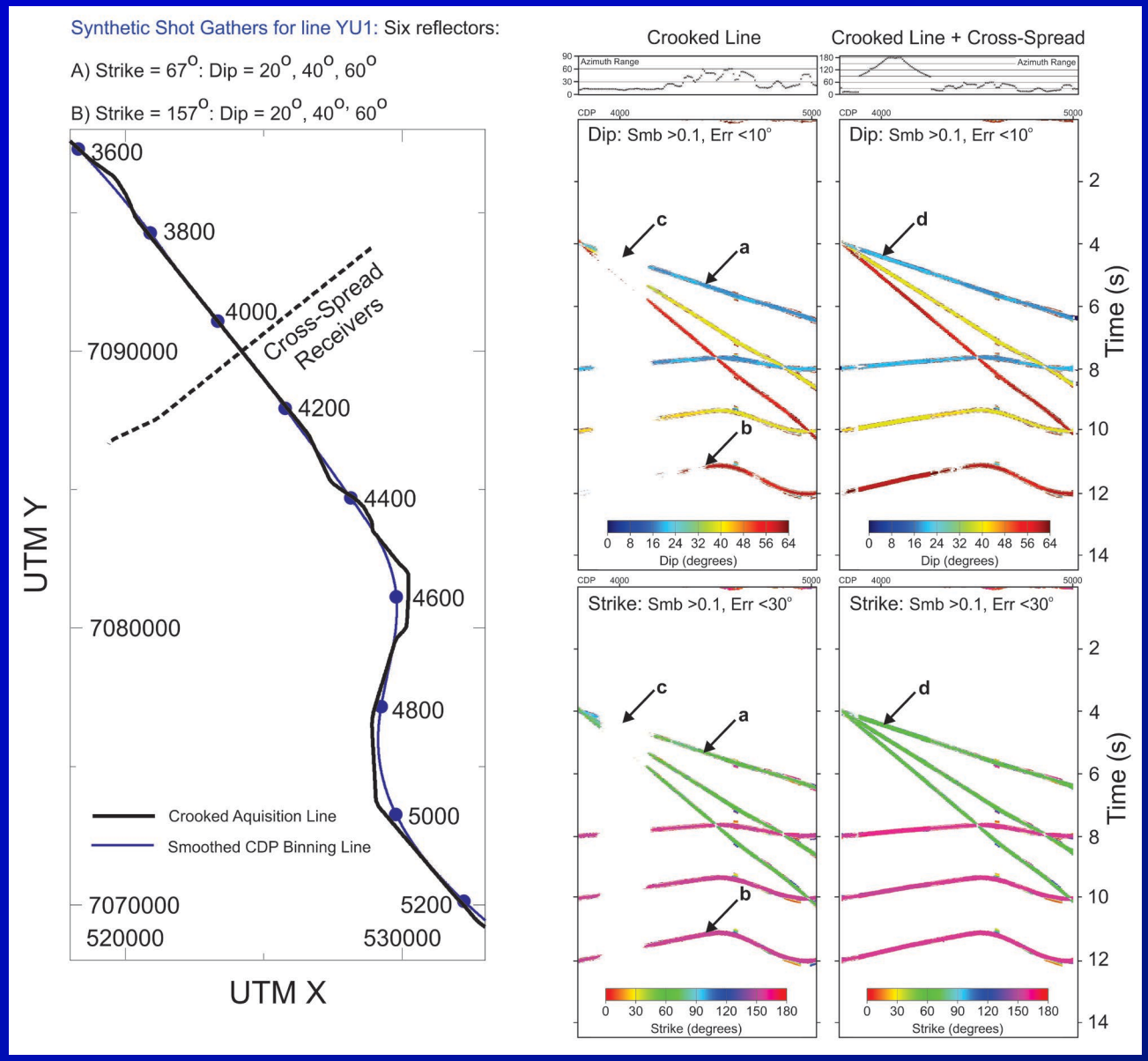
- Seismic image degraded owing to scatter of reflection points
- Scatter of reflection points allows estimation of orientation of planar reflector
- Low range of source-receiver azimuths where seismic line is straight

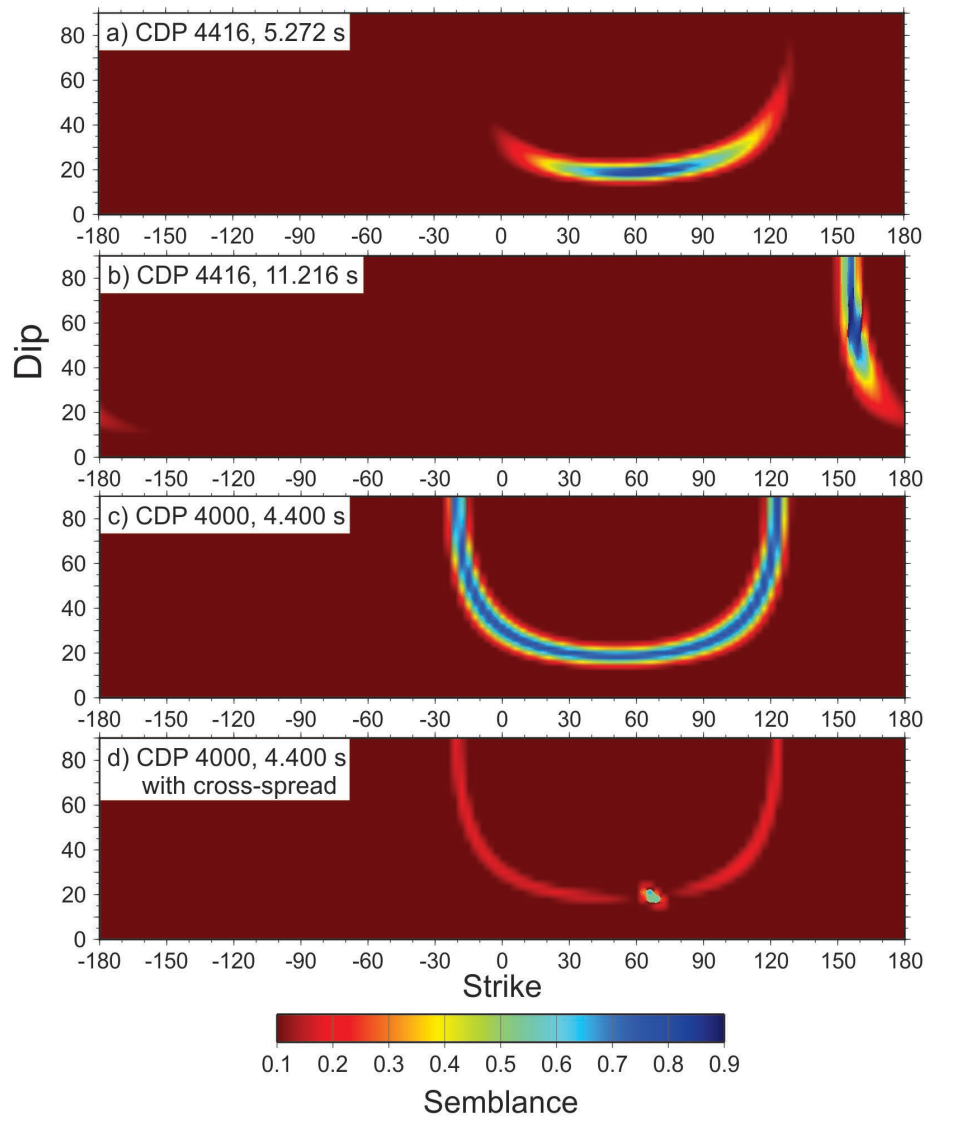
Synthetic Reflector Orientation and Estimation Errors



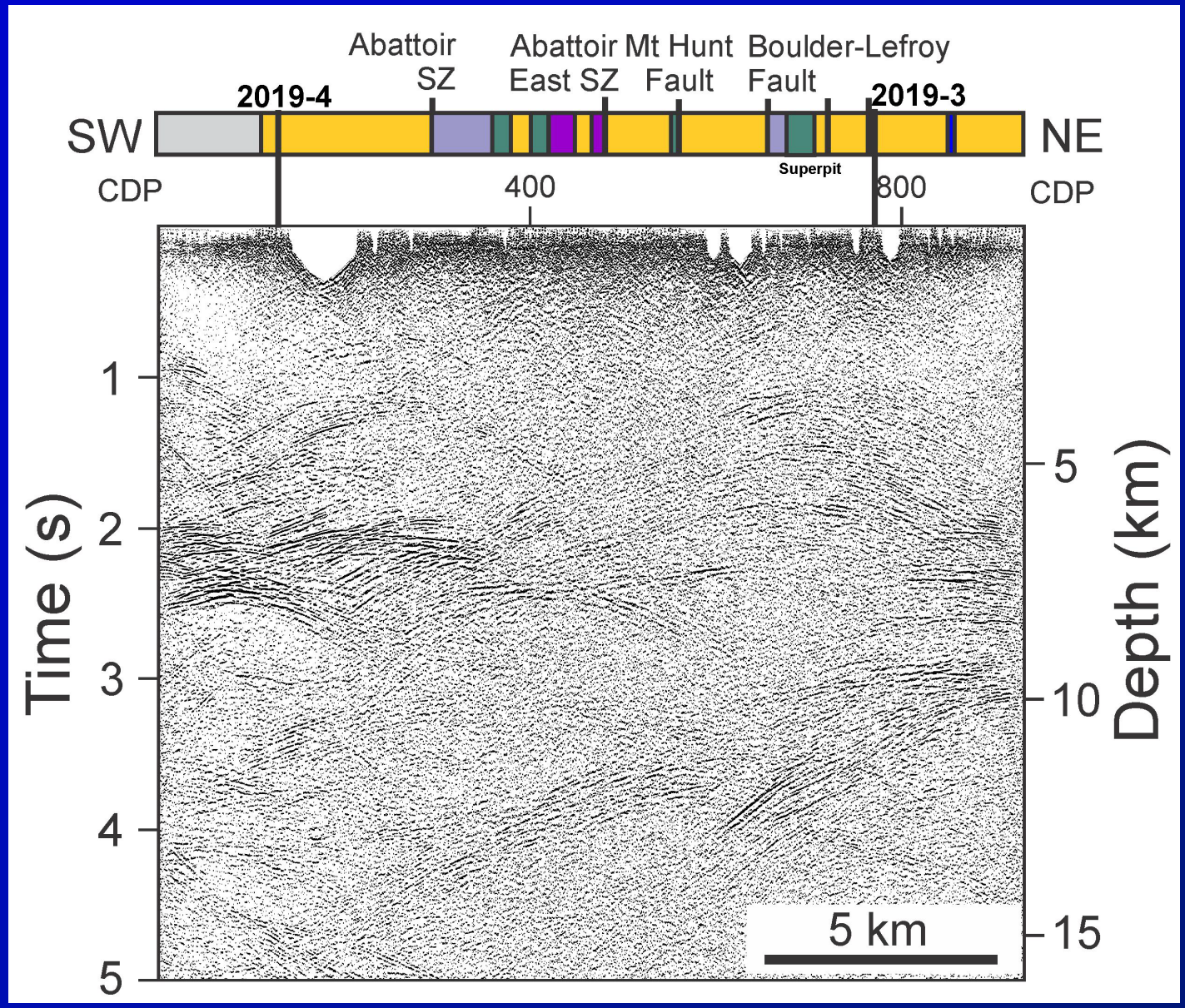
- Compute semblance along trial T-X trajectories in prestack data for various reflector dips and strikes
- Dip and strike angles of reflectors well resolved where semblance, i.e. coherency, is high **and** errors are low
- Threshold used to remove poor quality results, e.g semblance > 0.1 and err <10^{o}
- No good quality results where seismic line is straight, i.e. range of source-receiver azimuths is low

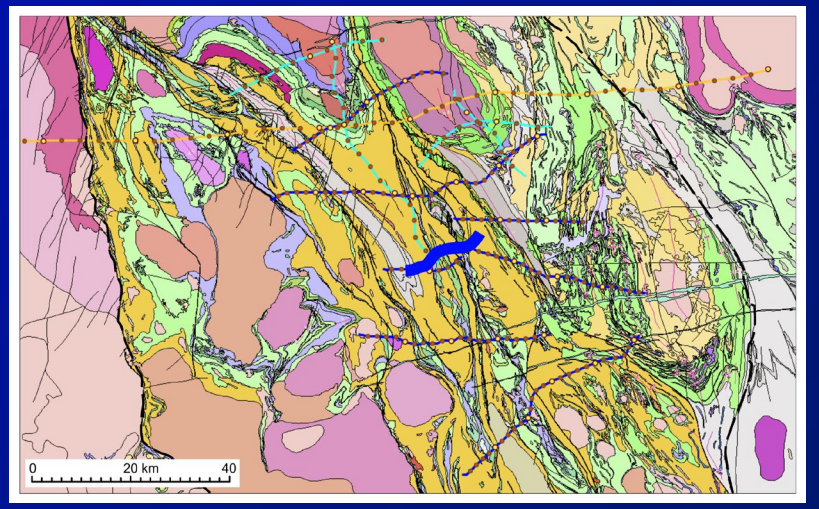
Offine Receivers Reduce Tradeoff Between Dip and Strike





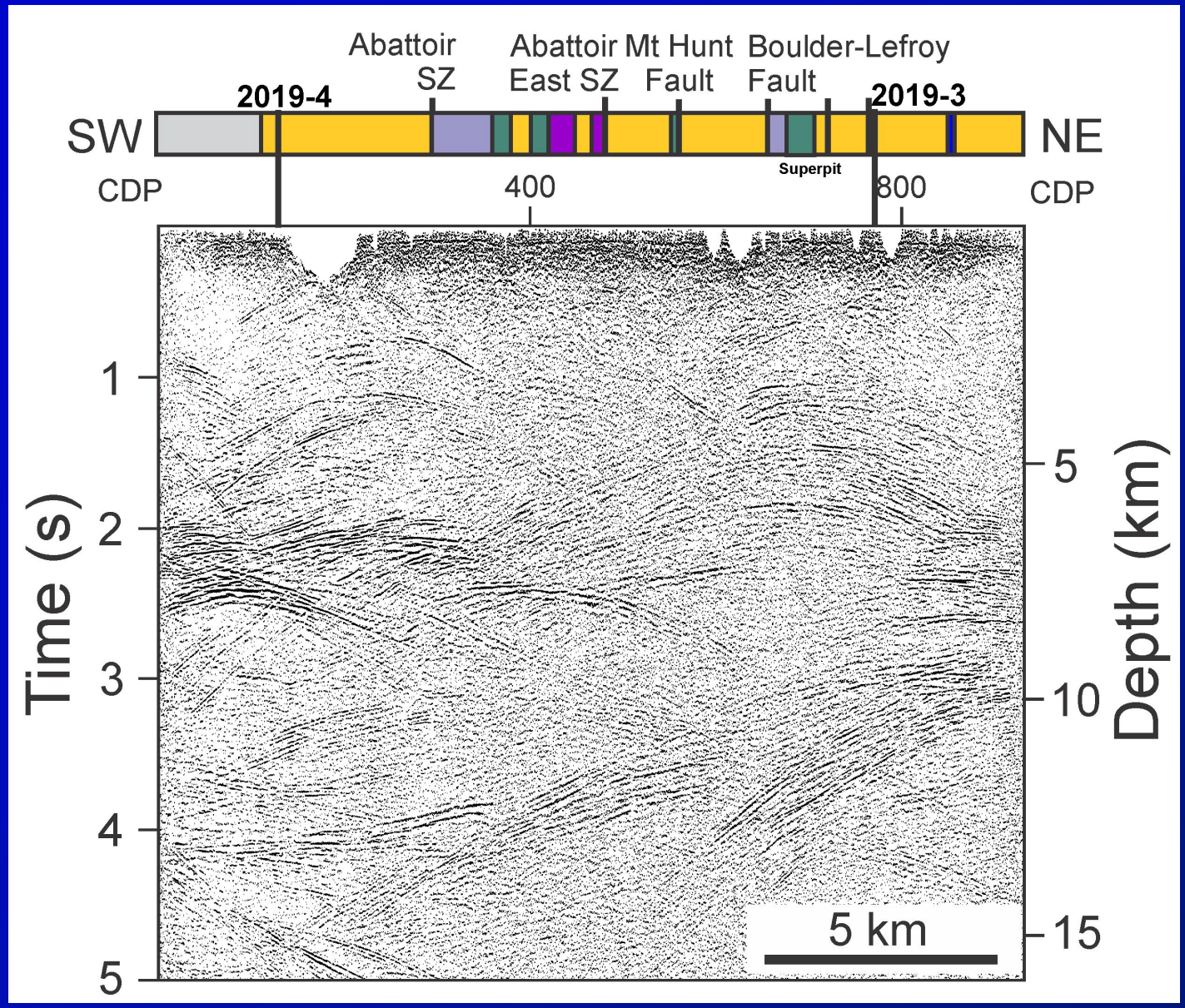
DMO Stack: 1999-Y3

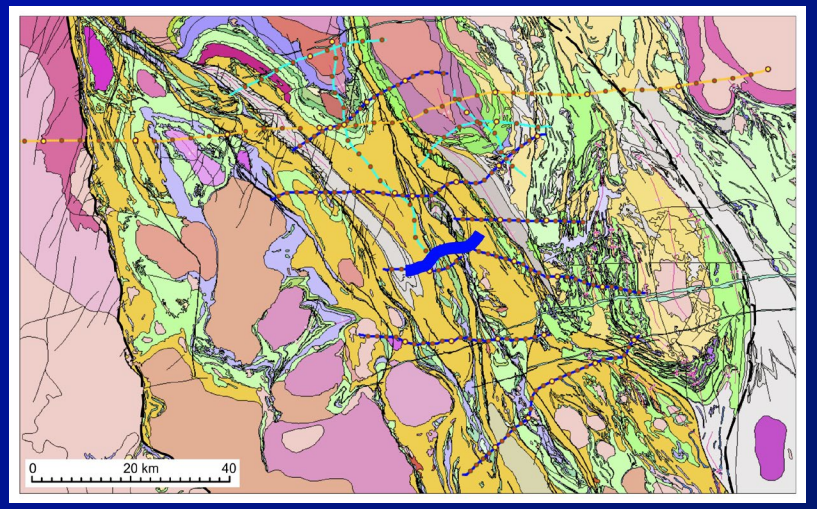




- 2-D dip moveout (DMO) correction handles correctly all inline dips
- 2-D DMO stack degraded by incorrect handling of cross-dipping reflections
- 3-D DMO stack or 3-D PSTM requires more survey coverage around crooked line

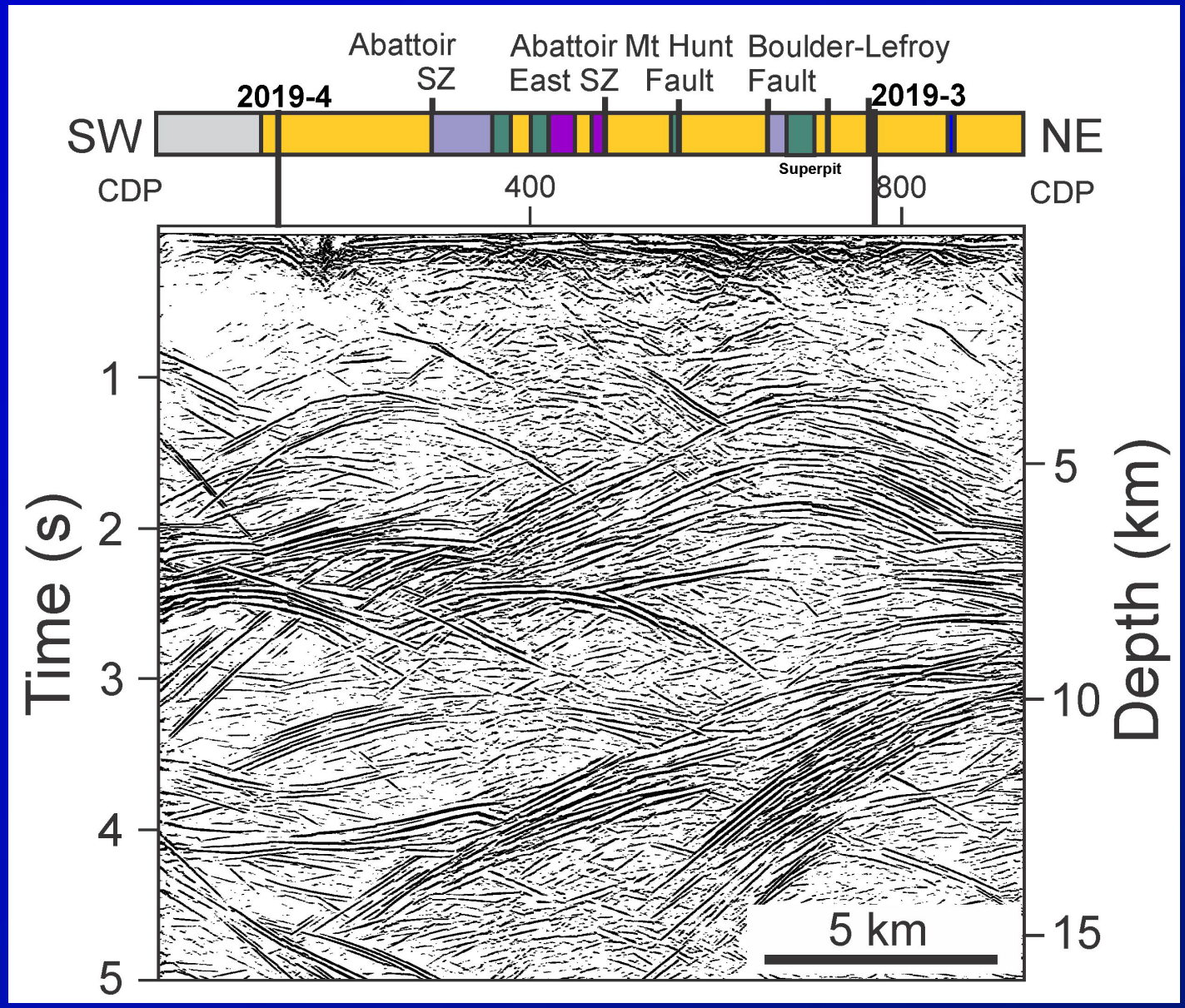
3-D Stack with Single CDP Gather

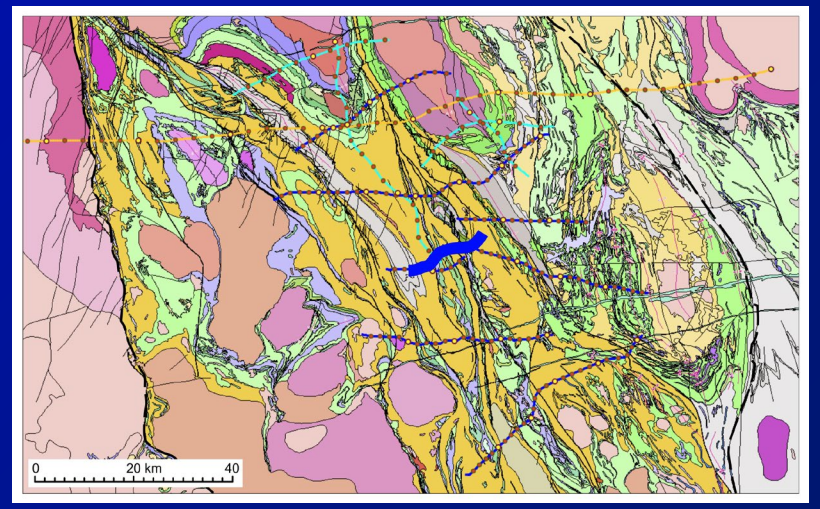




- 3-D stack uses estimated dip and sttike to accurately include out-of-plane reflections
- Equivalent to generalized cross-dip correction for single CDP
- Reflection near ~4.0 s at CDP 1-400 is much clearer on 3-D stack as out-of-plane origin is treated more accurately

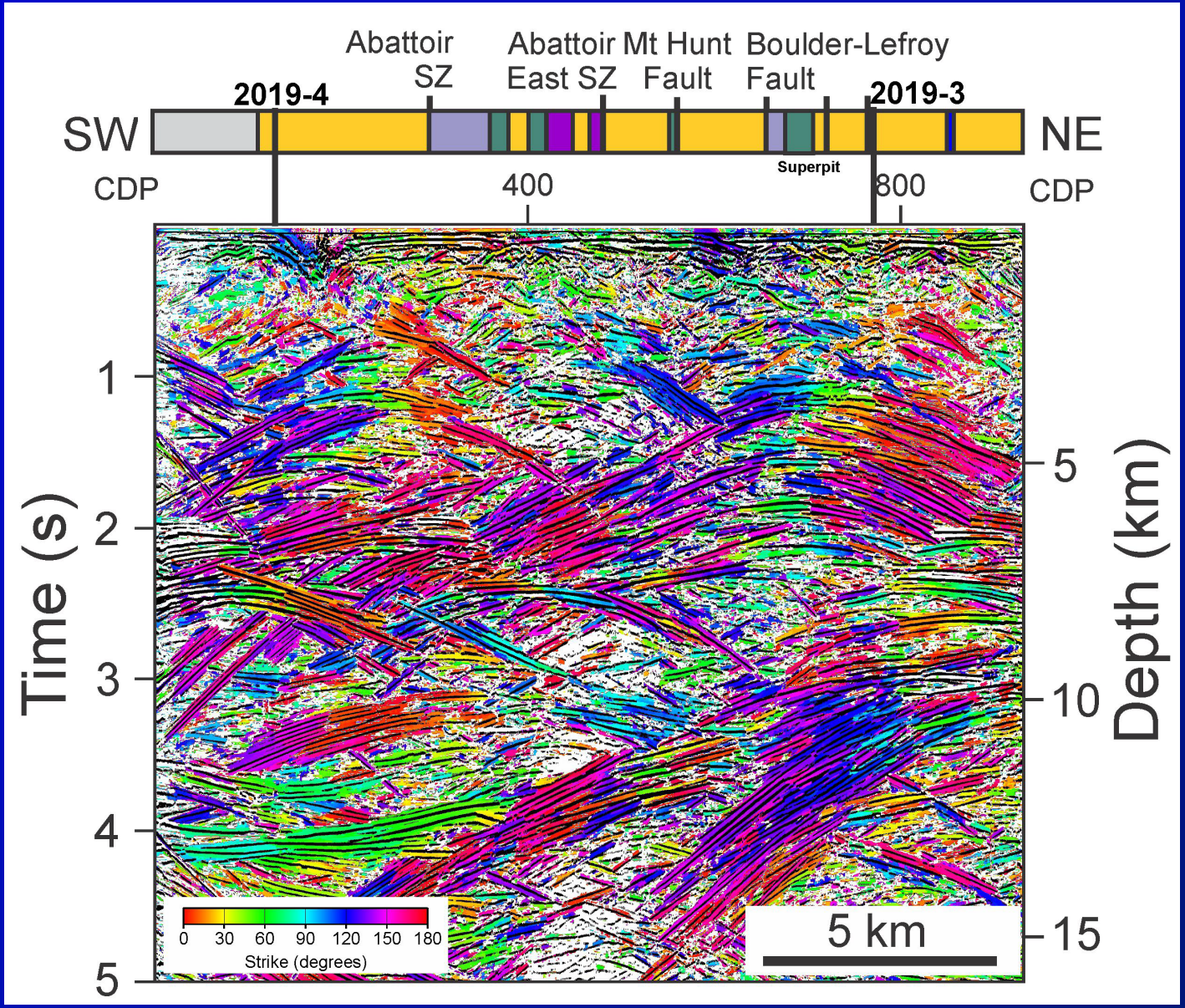
3-D Stack with 64 CDP Supergather





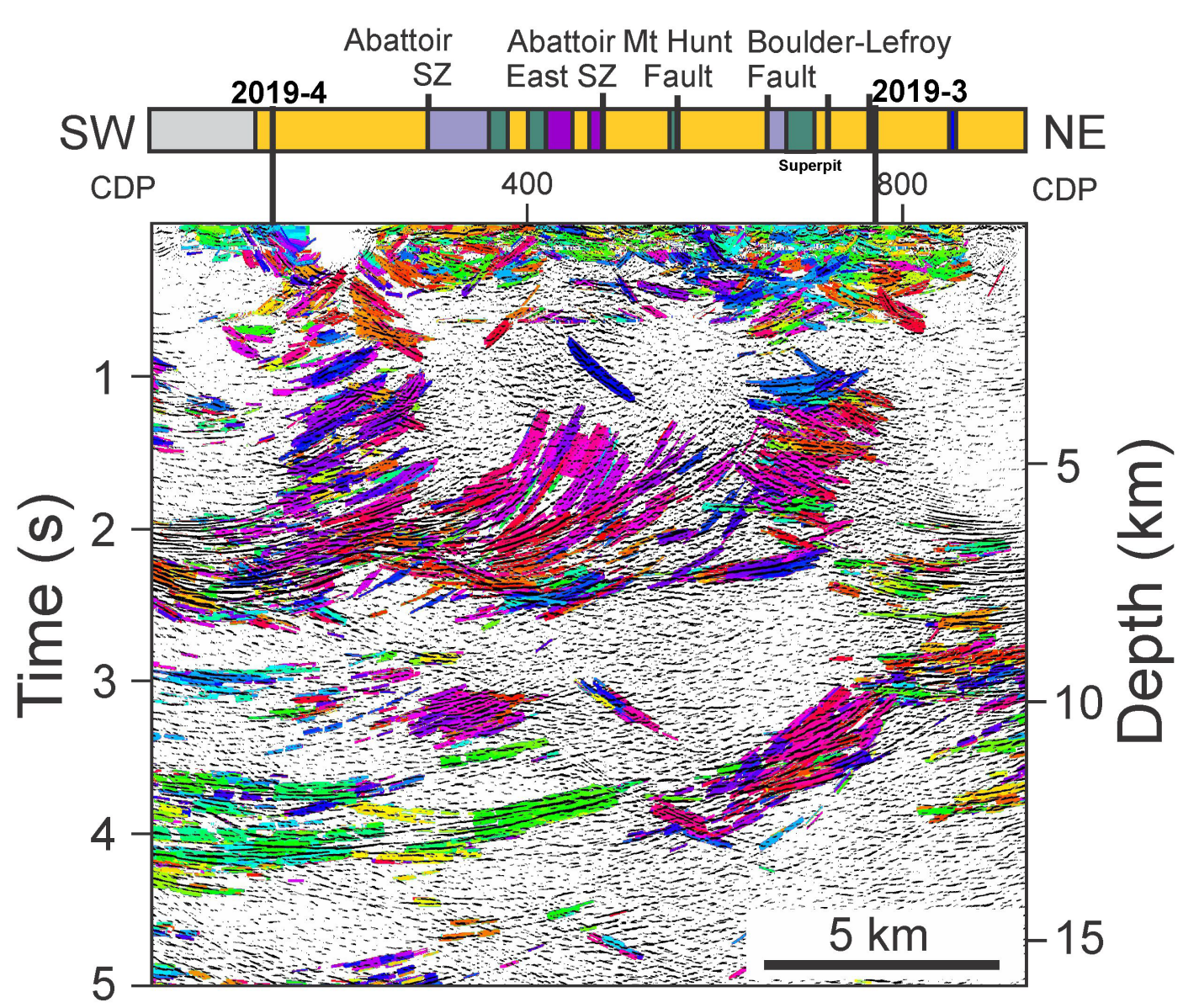
- Lateral coherency of stacked reflections can be increased by including more CDP
- Dimensions of subsurface planar reflector are increased
- Kalgoorlie lines require data from 64 adjacent CDPs (1.3 km) to resolve reflector dip and strike

3-D Stack with Reflector Strike



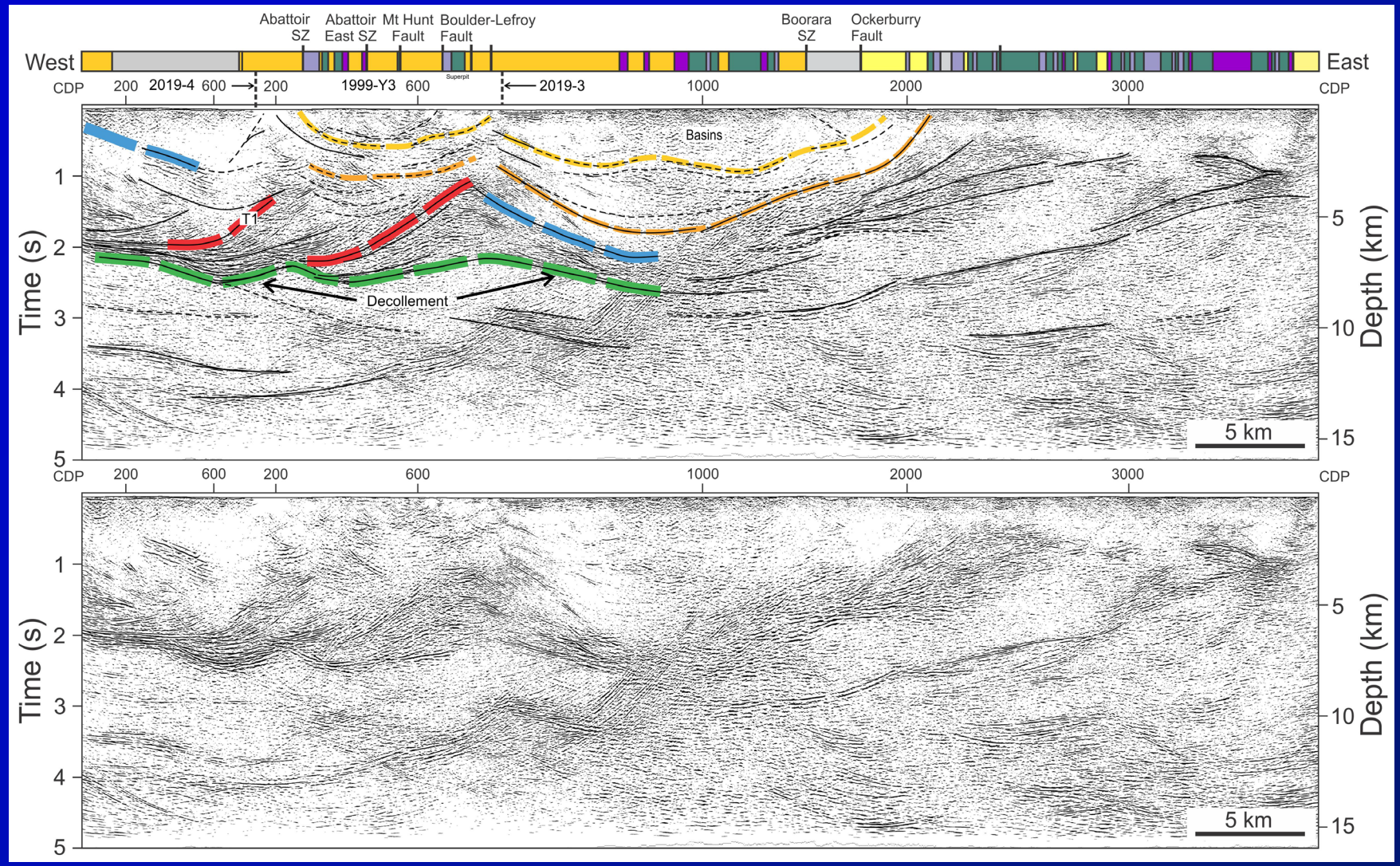
- With sufficient source-receiver azimuths in supergather, reflector dip and strike can be recovered
- Line oriented along ~054°
- In-line reflectors have strike of ~144° (magenta)
- Many reflectors originate out-of-plane of seismic section, e.g. green, cyan
- Green reflection at 4 s strikes ~060°, parallel to seismic line

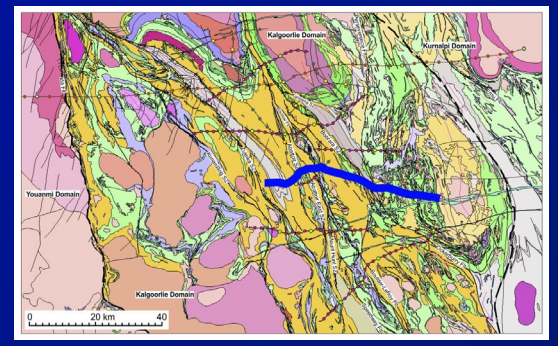
2-D Migrated 3-D Stack with Reflector Strike



- Stack does not represent true subsurface position of reflectros
- 2-D migration positions reflections at true position assuming seismic velocity known and reflections originate in plane of section (many do not!)
- In-line reflectors have strike of ~144° (magenta)
- Many reflectors originate out-of-plane of seismic section, e.g. green, cyan
- Green reflection at 4 s strikes ~060°, parallel to seismic line

Extension and Basin Formation at Kalgoorlie Gold Field

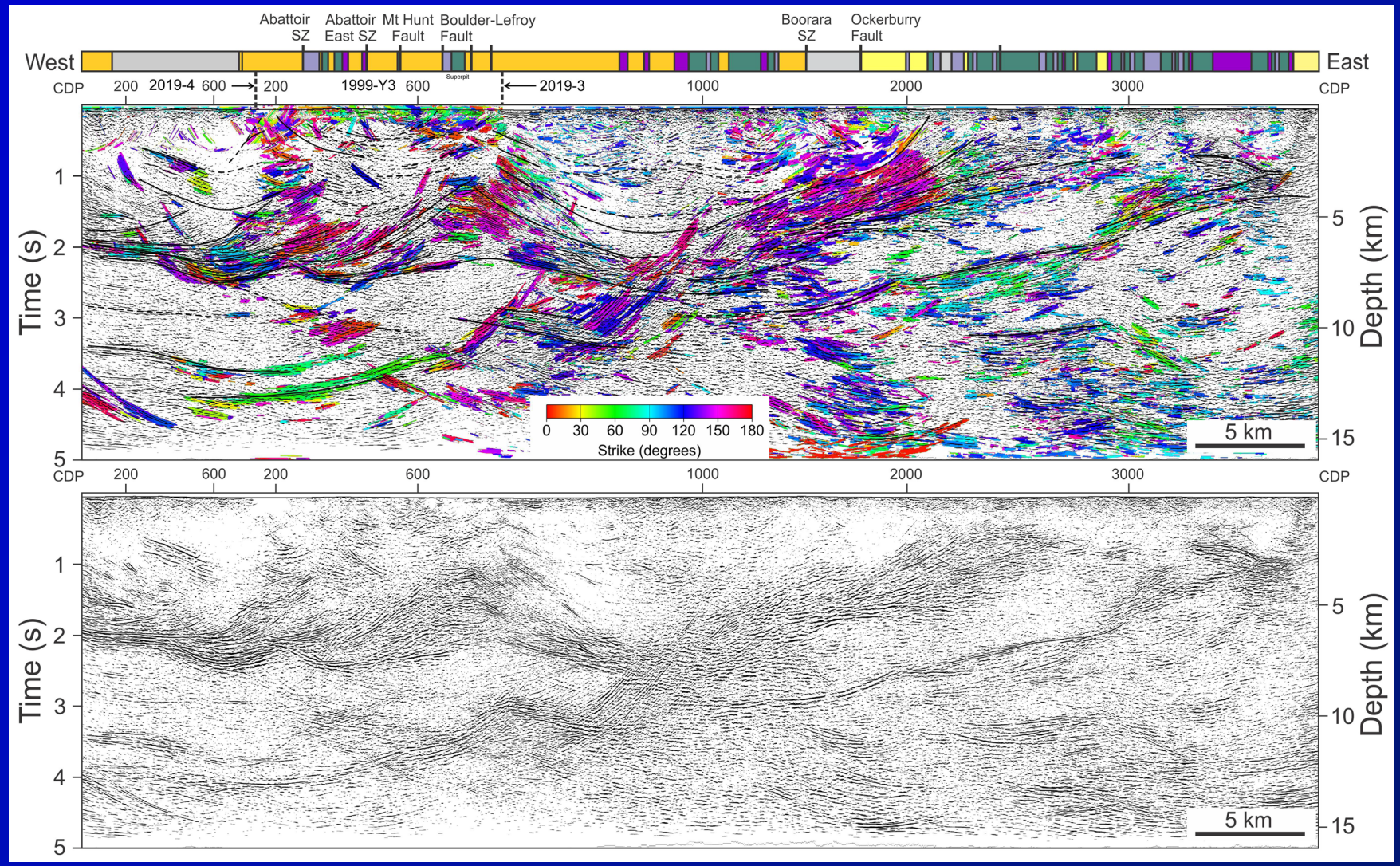


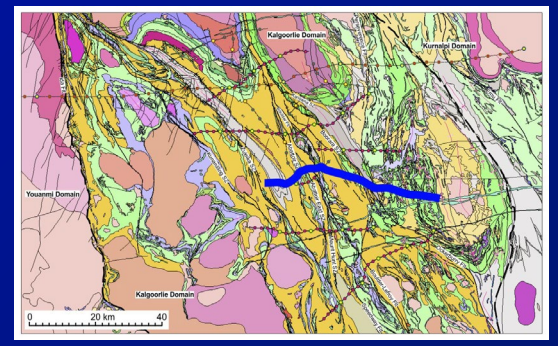


- Listric reflectors flattern into (faulted?) decollement
- Dipping reflectors truncated above by low amplitude reflections
- 1-2 s deep synforms formed above deollement
- In east, strata tilted to west due to large pluton

- Merged vibroseis section from hi-res lines 2019-3/4 and line 1999-Y3

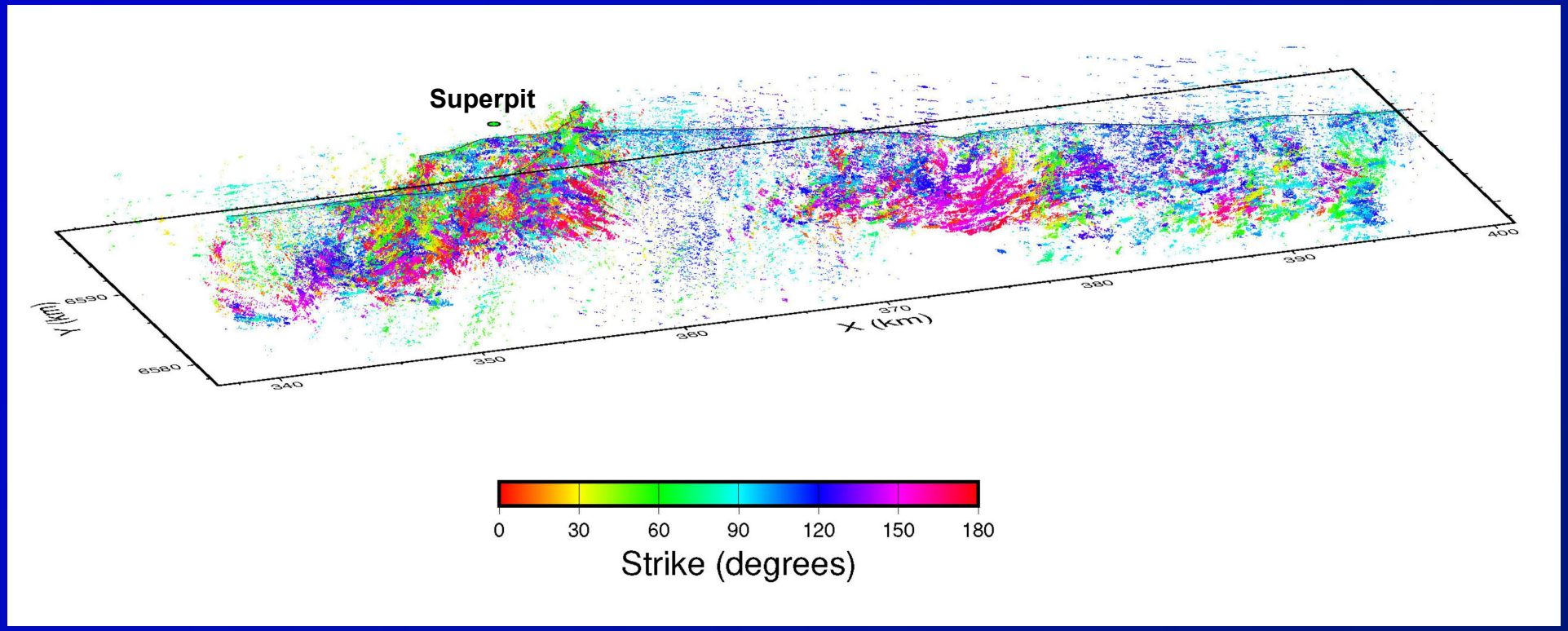
Reflector Strike Across Central (Kalgoorlie) Domain





- Many dipping reflectors at 1-2 s strike ~150°
- Change in reflector strike above transparent granite

3-D Display of Reflector Point Cloud

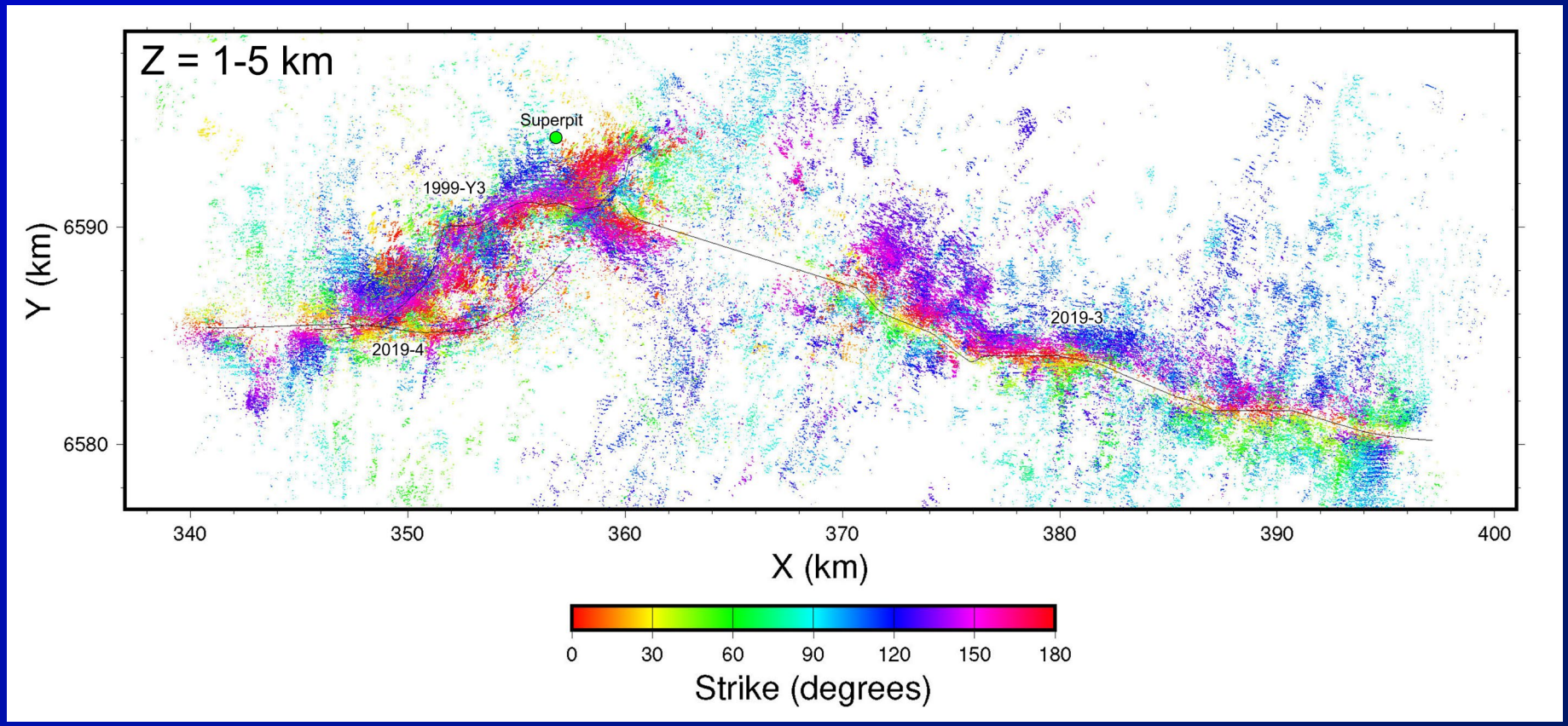


- 3-D perspective view through semi-transparent Earth
- Lower reflectivity east of Superpit indicates volcaniclastic basin
- In east, change from red to blue and green represents different volcanic sequences over large granite

- Reflection points can be calculated in 3-D using dip, strike and seismic velocity
- Reflectors from several lines can be merged into single image
- Cloud of reflection points displayed in 3-D viewed from SW
- 3-D structures only partially imaged

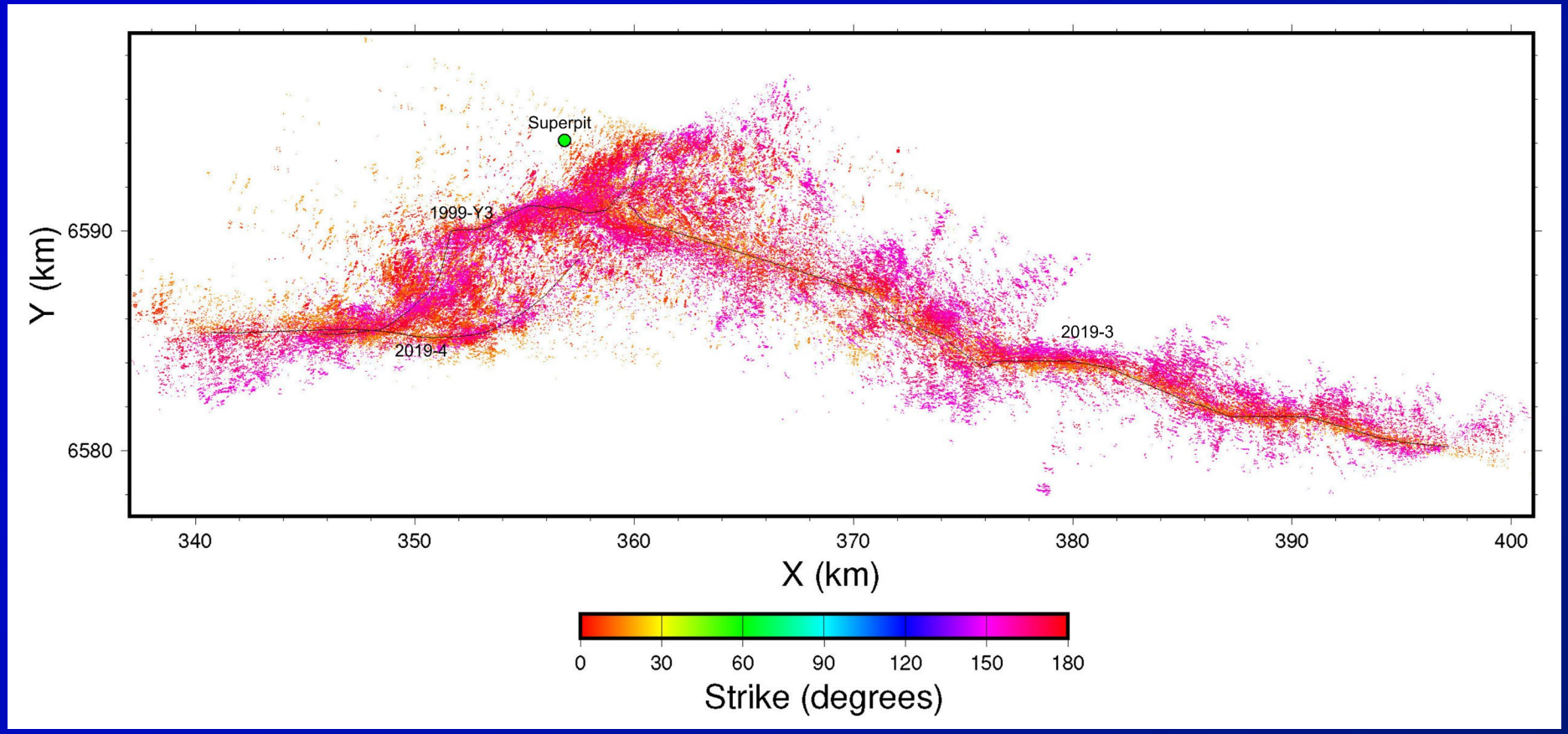
Depth Slice of Reflector Point Cloud

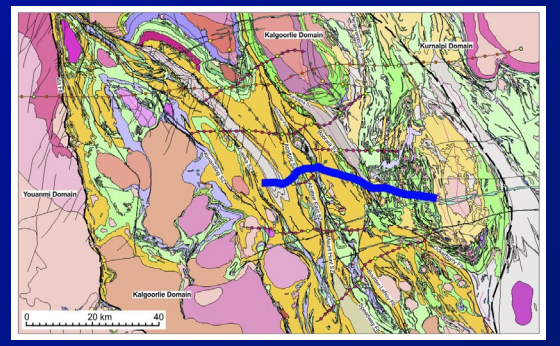
- Depth slices provide alternative display
- Red/magenta reflectors originate close to ENE/E-trending seismic lines
- Green/blue reflectors are parallel to seismic lines, and more distant
- Reflectors can orignate up to 10 km from seismic lines



- Lower reflectivity east of Superpit indicates clastic basins: shallow (cyan) and deep (blue)?

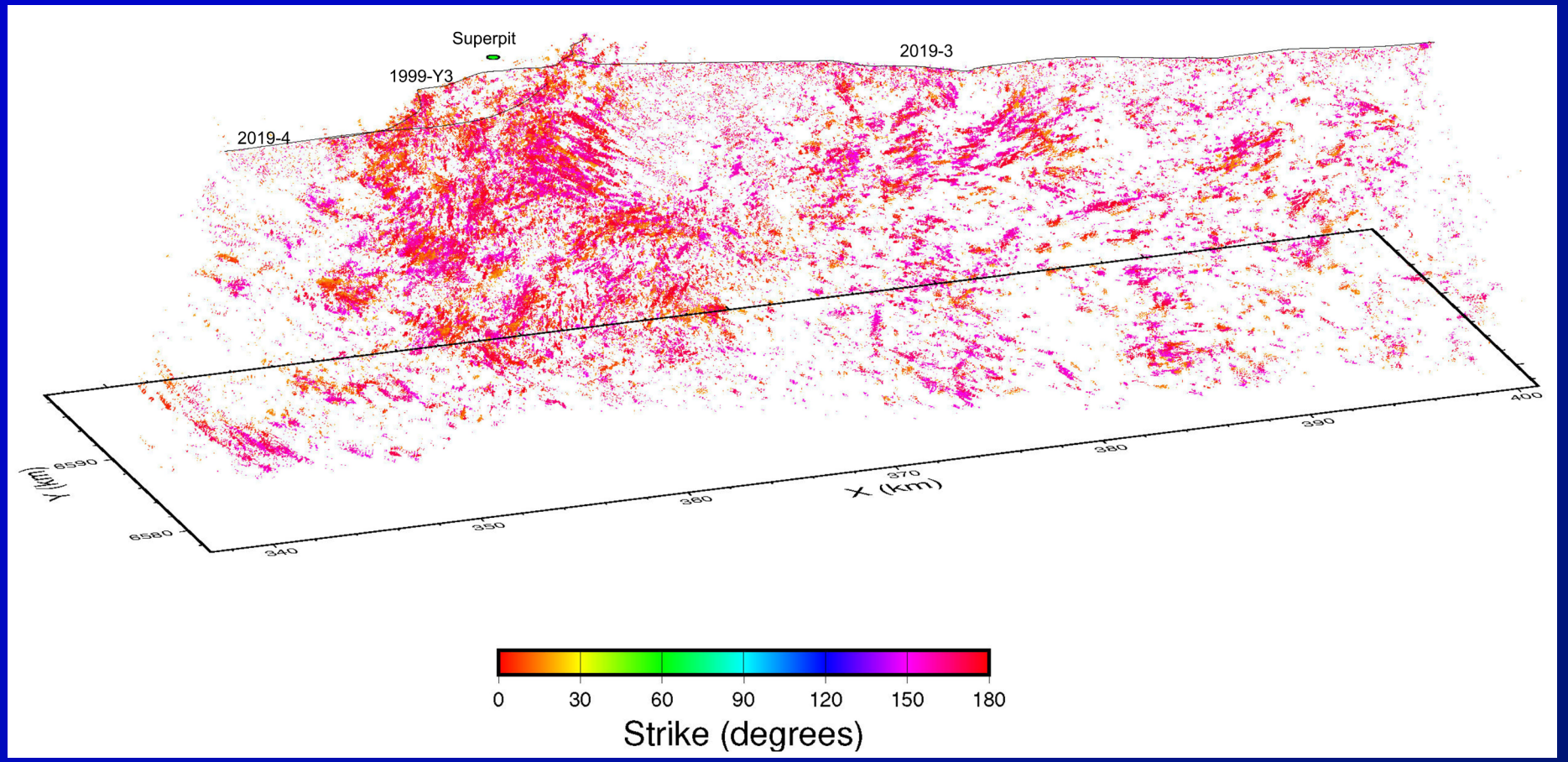
View From Above of NNW- to N-Striking Reflectors





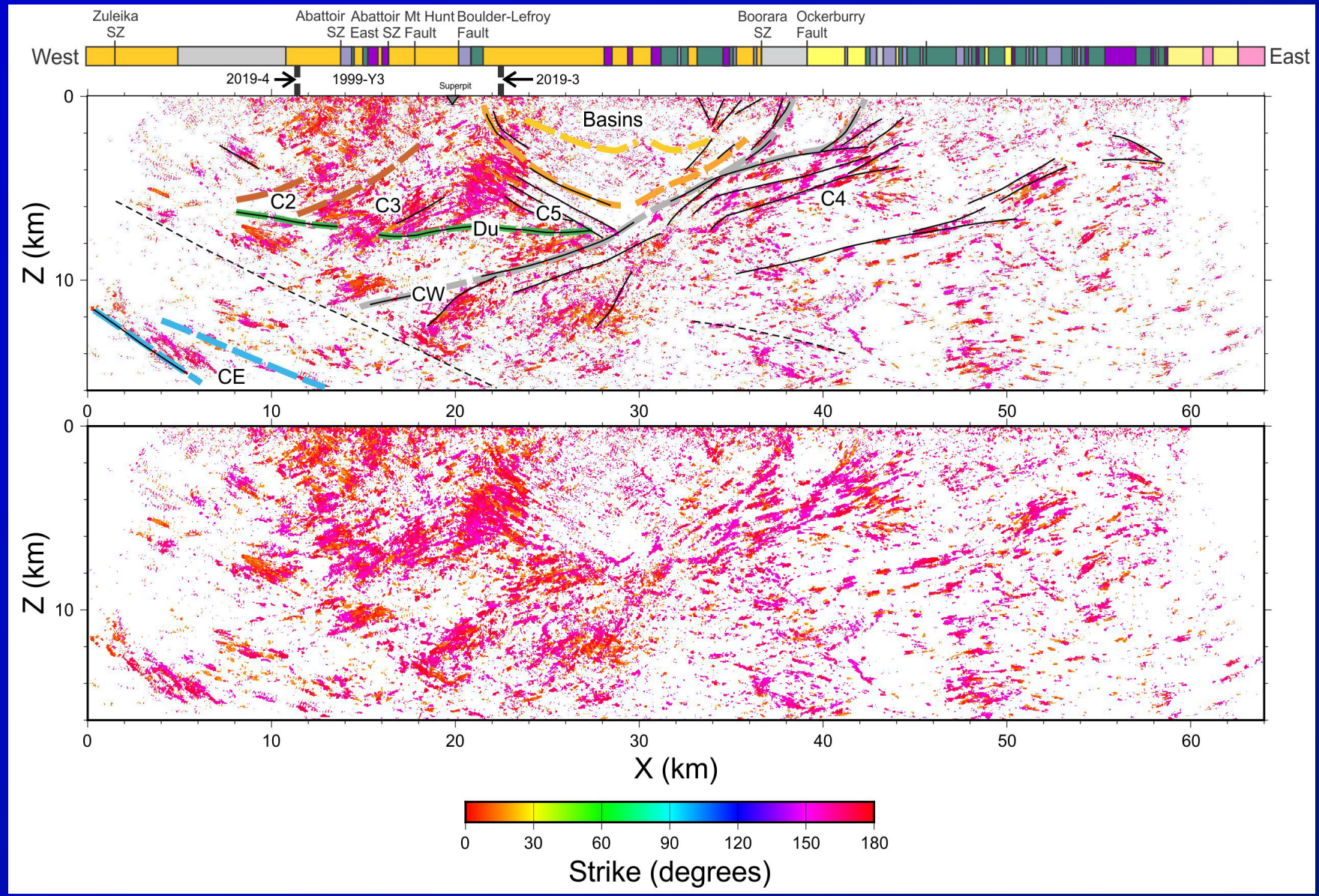
- Reflectors striking parallel to NNE-trending structures: 150° to 020°
- Depth 0-16 km

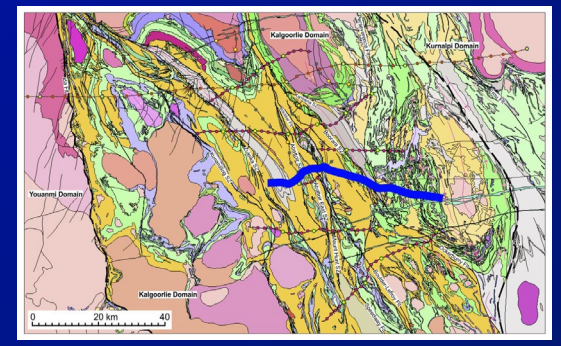
Oblique View of Point Cloud from SSW for Strike 150-020°



- 3D perspective view through semi-transparent Earth
- Some 3-D structures stand out:
  - E-dipping mid-crustal ramp
  - Deep antiform
  - Volcanics over large pluton at east end of line

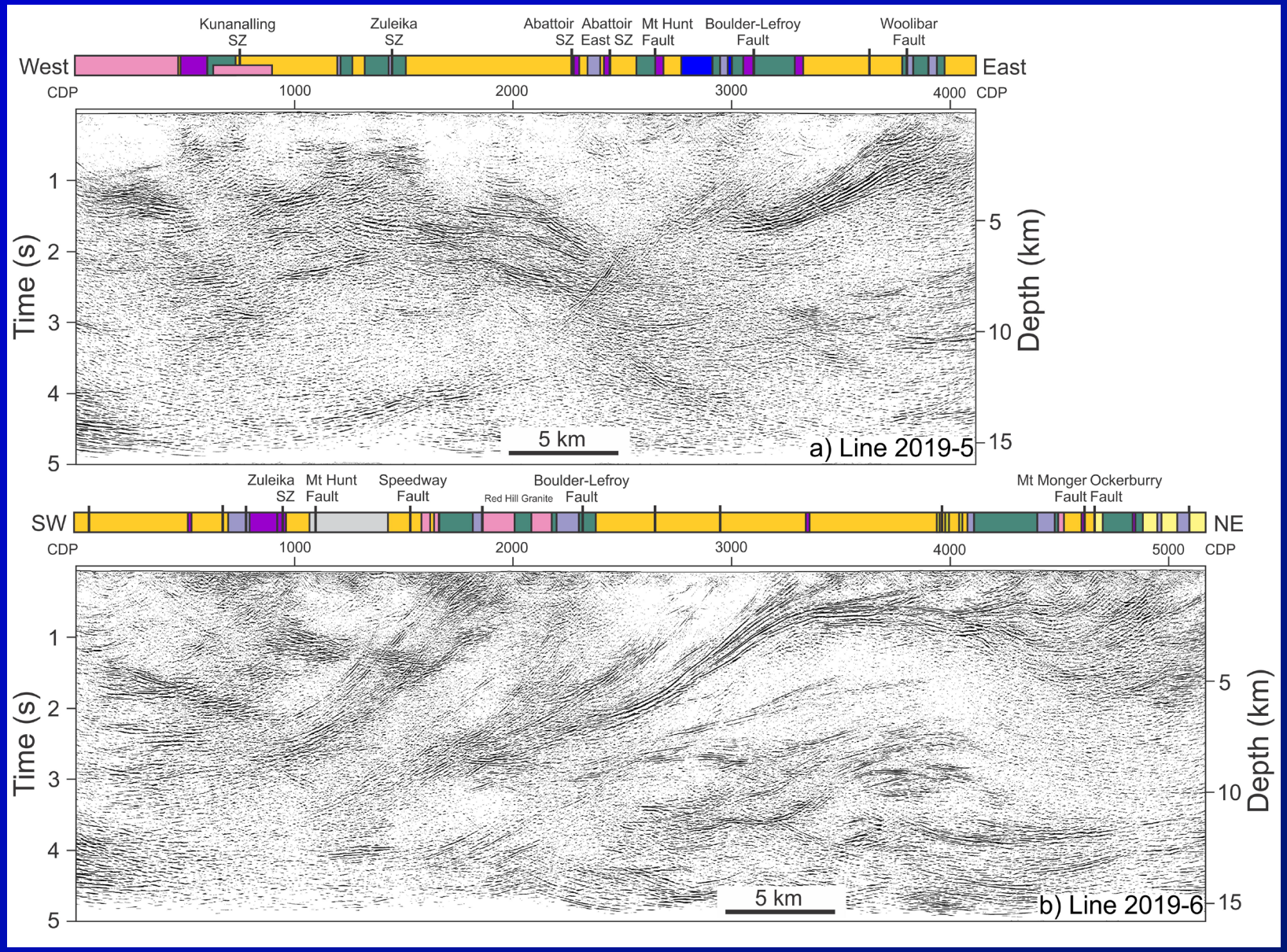
West-Dipping Shear Zone in Central (Kalgoorlie) Domain

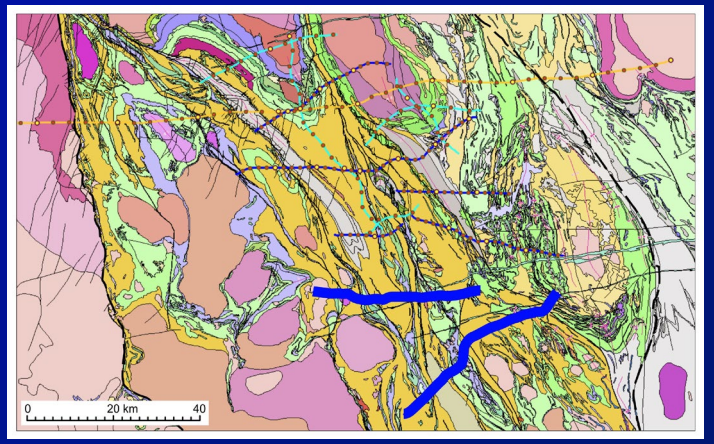




- Major W-dipping fault extends to >10 km depth
- Underlying east-dipping shear zone at 10-15 km depth in west
- Selection of specific strike orientation can reveal fault network

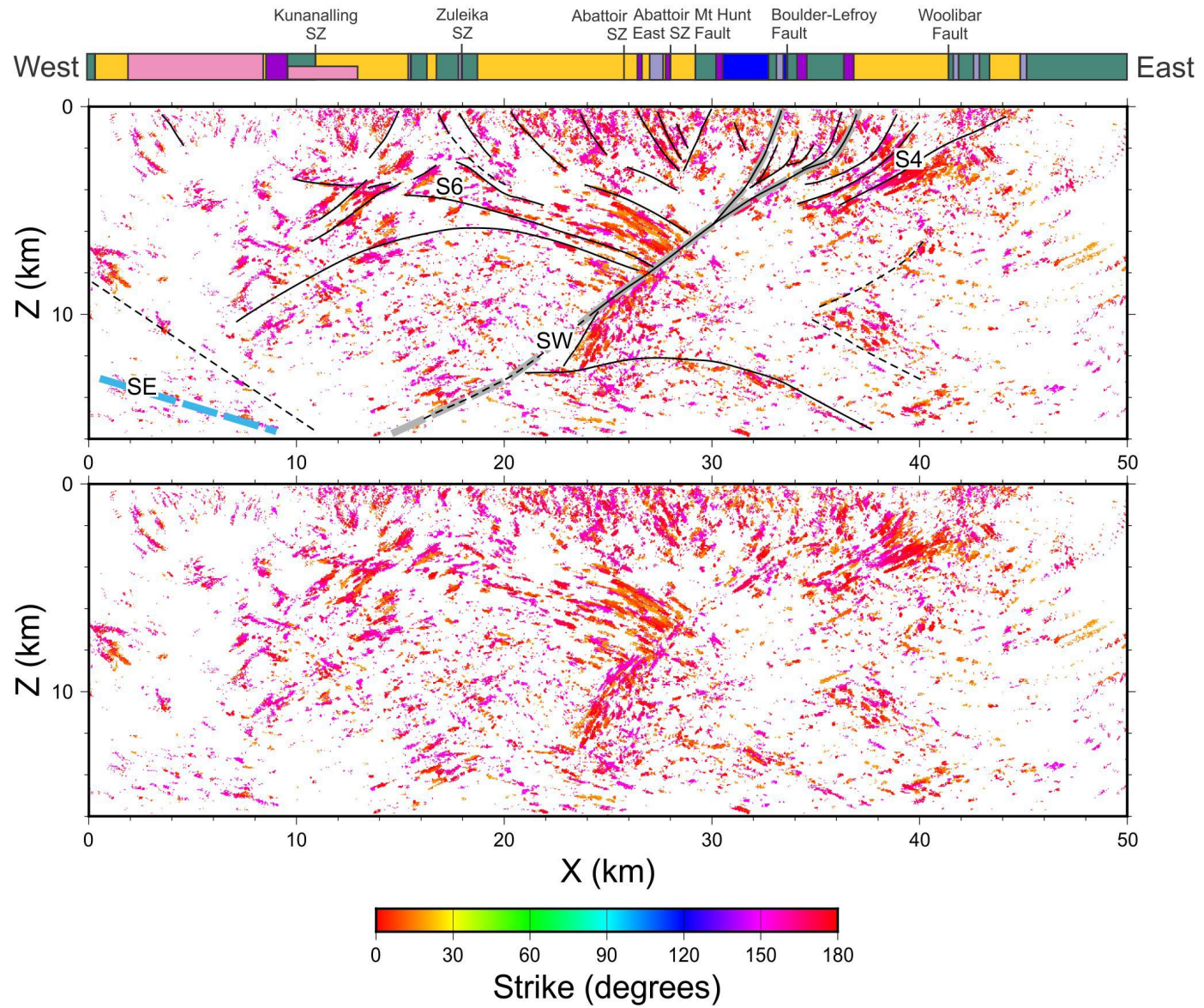
Southern (Kambalda) Domain

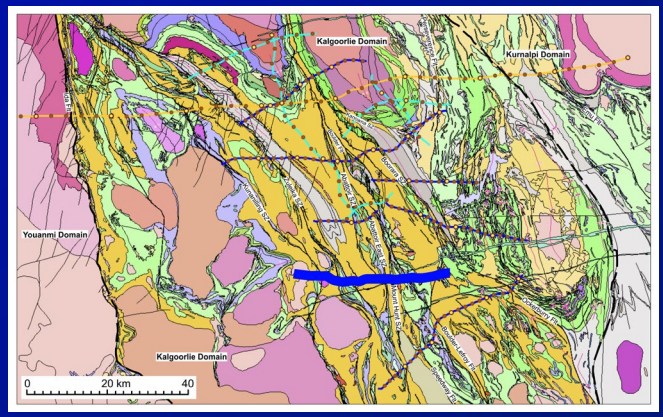




- Line 2019-5: normal offset between reflective units
- Line 2019-6: systematic dips to west
- Steeply dipping fault reflections cross shallowly dipping reflections

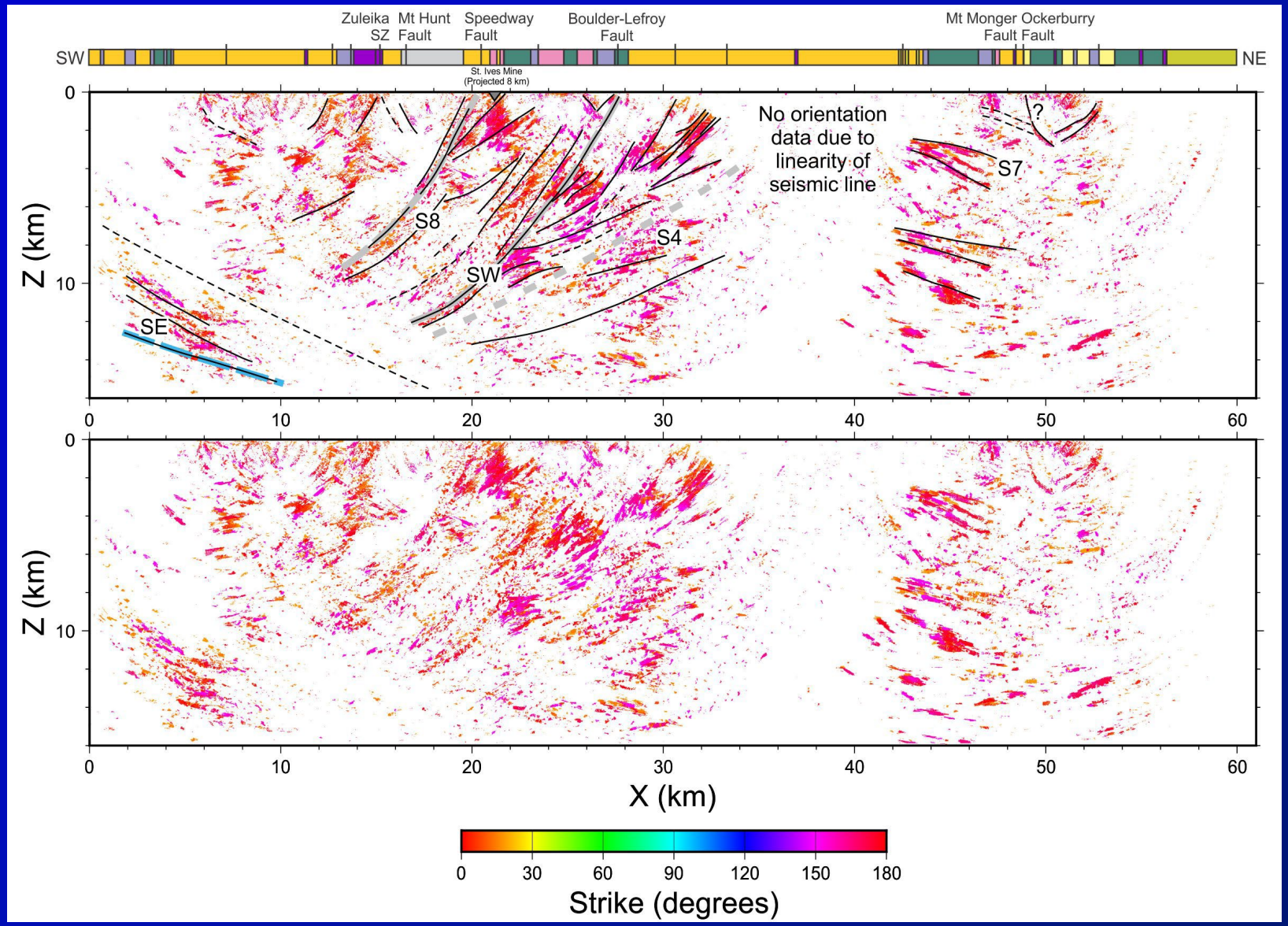
Flower Structure in Southern (Kambalda) Domain

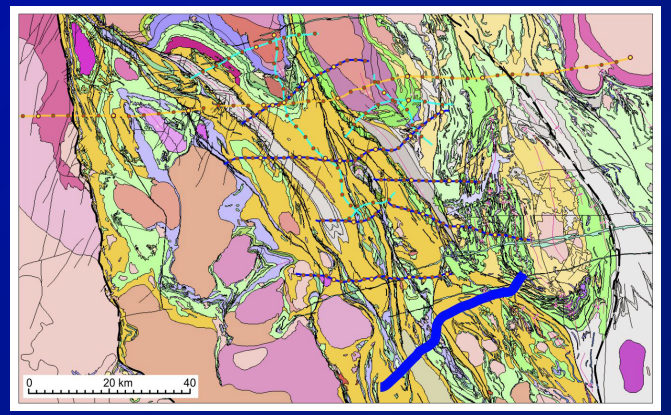




- Flower structure with major W-dipping fault extending to >10 km
- Mapped surface faults in hanging wall are typically <5 km deep
- Change in vergence of near-surface faults across Abattoir-Mount Hunt fault system
- Reflectors mostly correspond to faults and volcanic strata

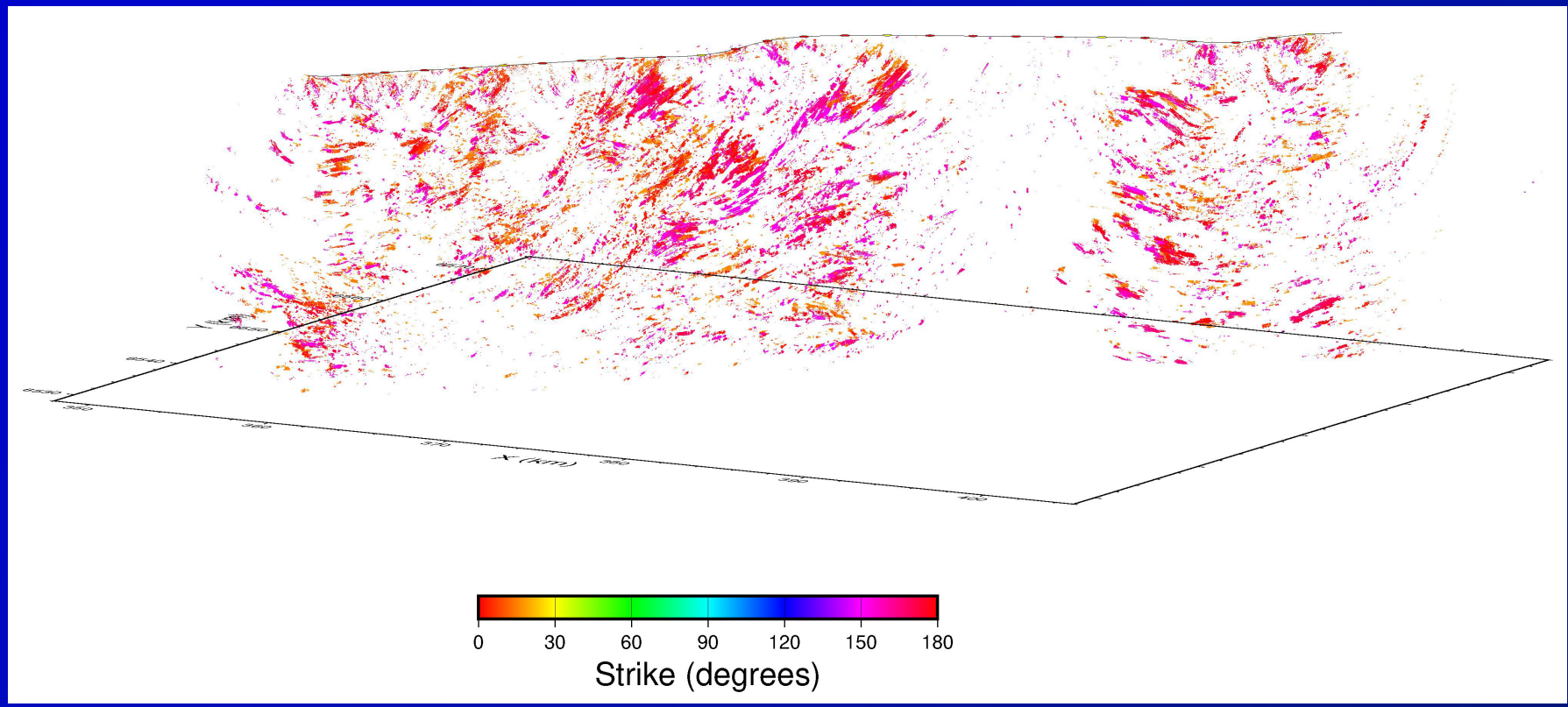
Systematic W-Dipping Faults in Southern (Kambalda) Domain

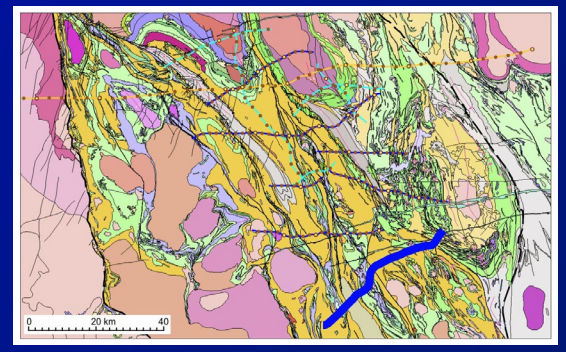




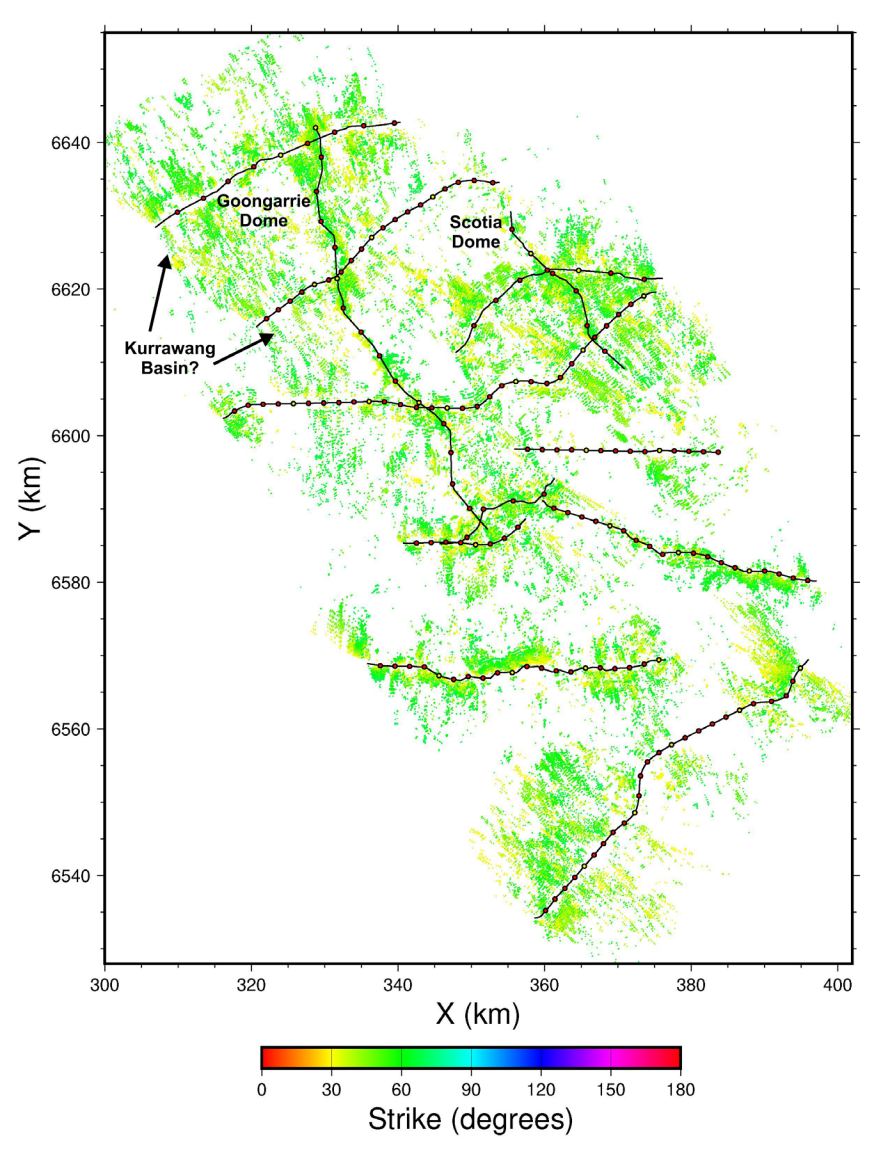
- Steeply dipping faults and volcanic stratigraphy trumcated at 10-15 km depth by E-dipping shear zone
- No data in linear section of profile
- Stratigaphy with different strike directions not shown

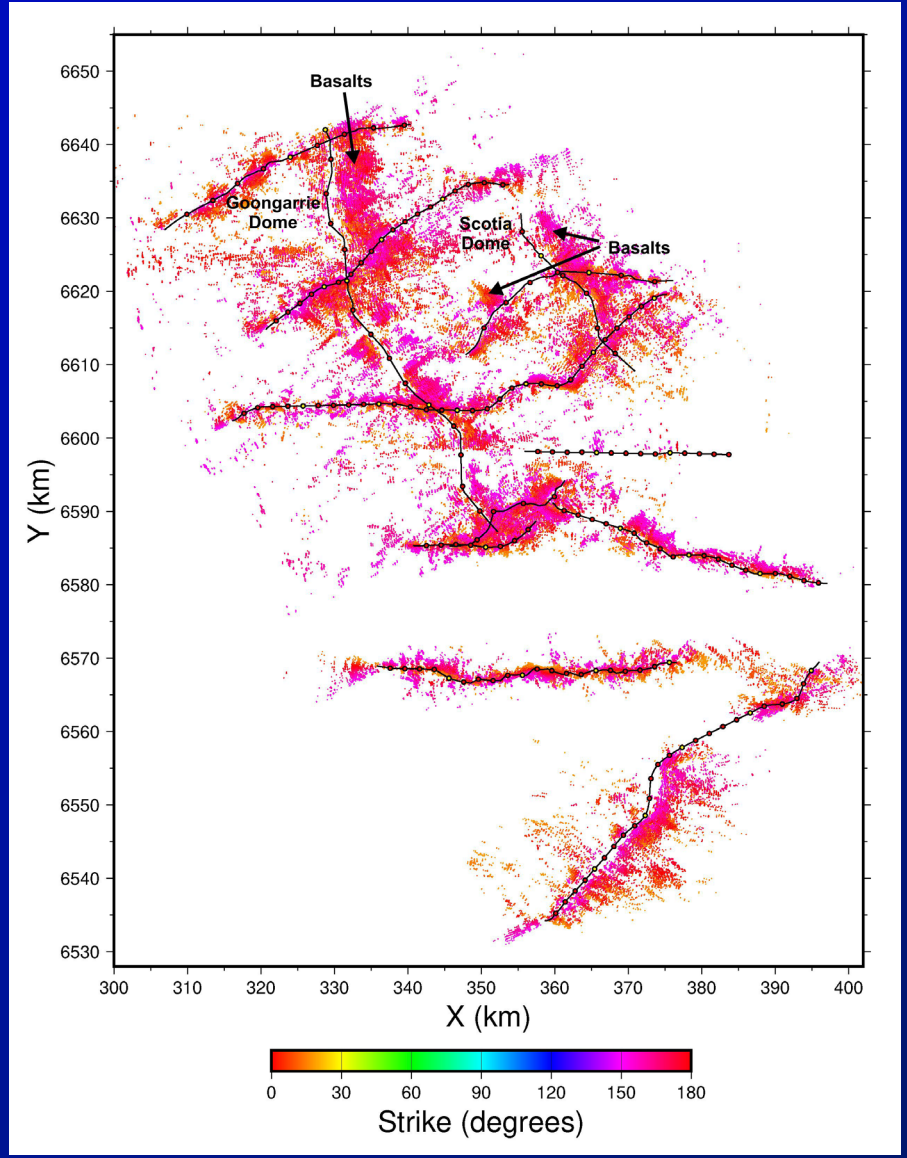
Line 2019-6: 3-D Migration Strike 150-020°: View from SSE

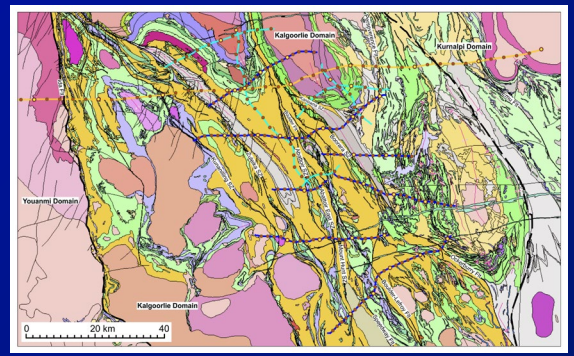




Full Survey 4-8 km Depth Slices of Strike

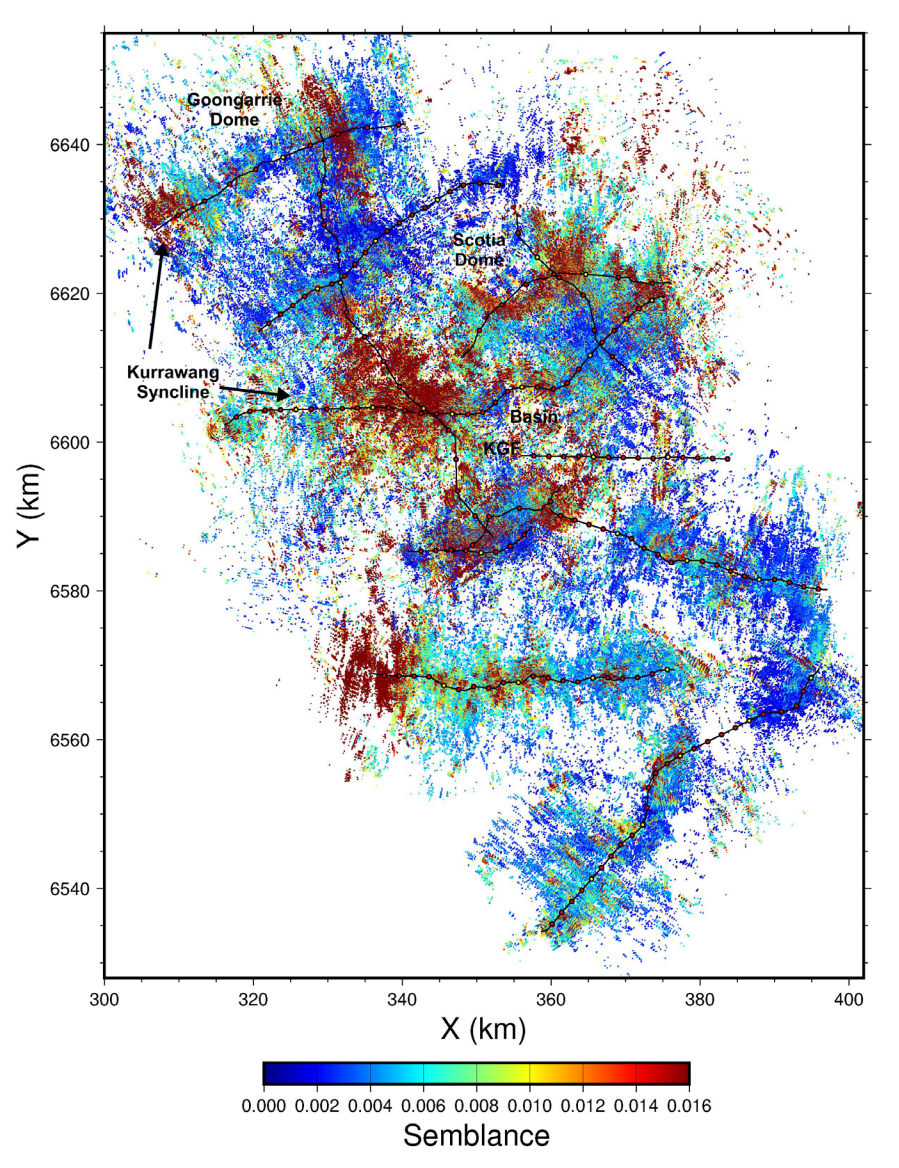


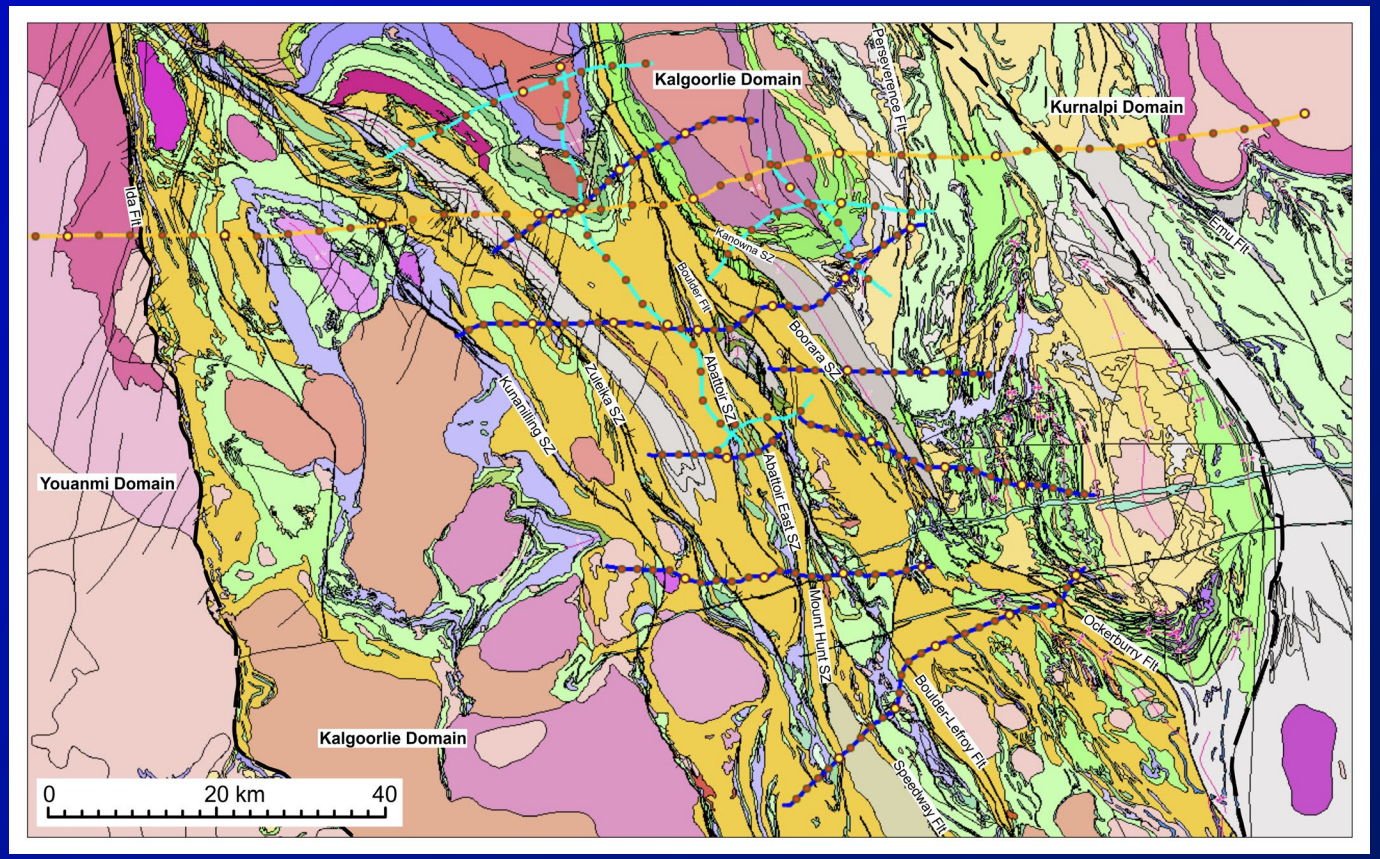




- Partial coverage over 100x100 km area
- Can identify basalts between and around northern granite domes
- Basin beneath Kurrawang Syncline also visible

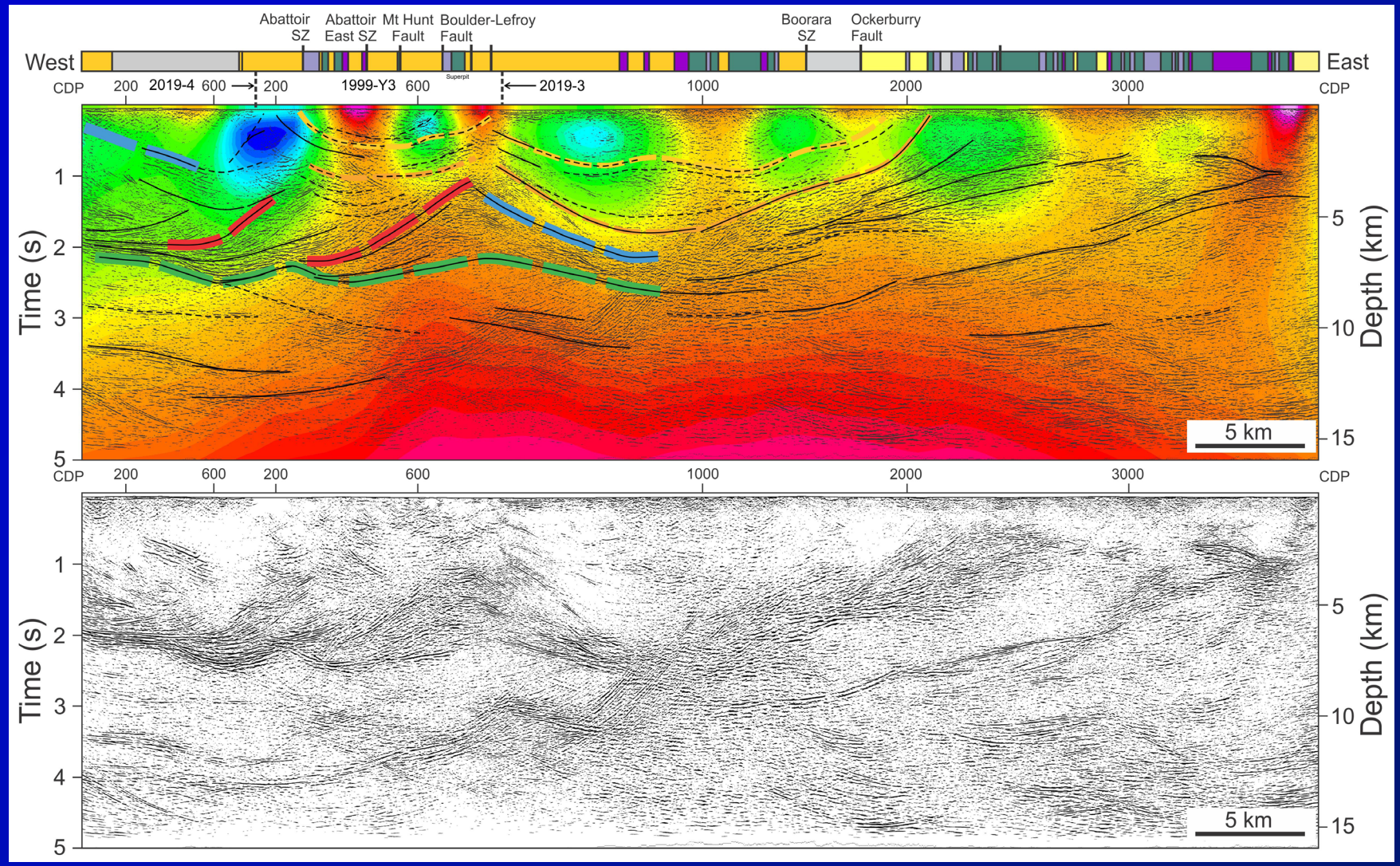
Full Survey 4-8 km Depth Slices of Semblance

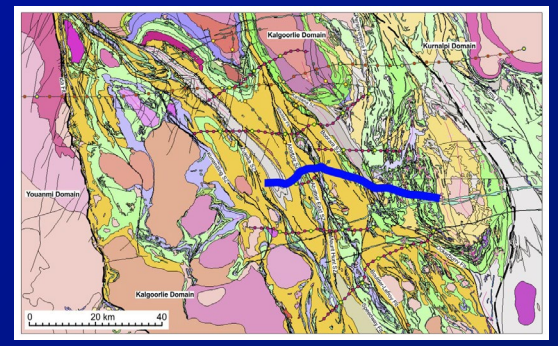




- Scotia Dome outlined by strong overlying volcanic reflections
- Basins west and east of Kalgoorlie Gold Field also visible(?)
- Beware of artefacts…

3D Gravity Inversion Across Central (Kalgoorlie) Domain

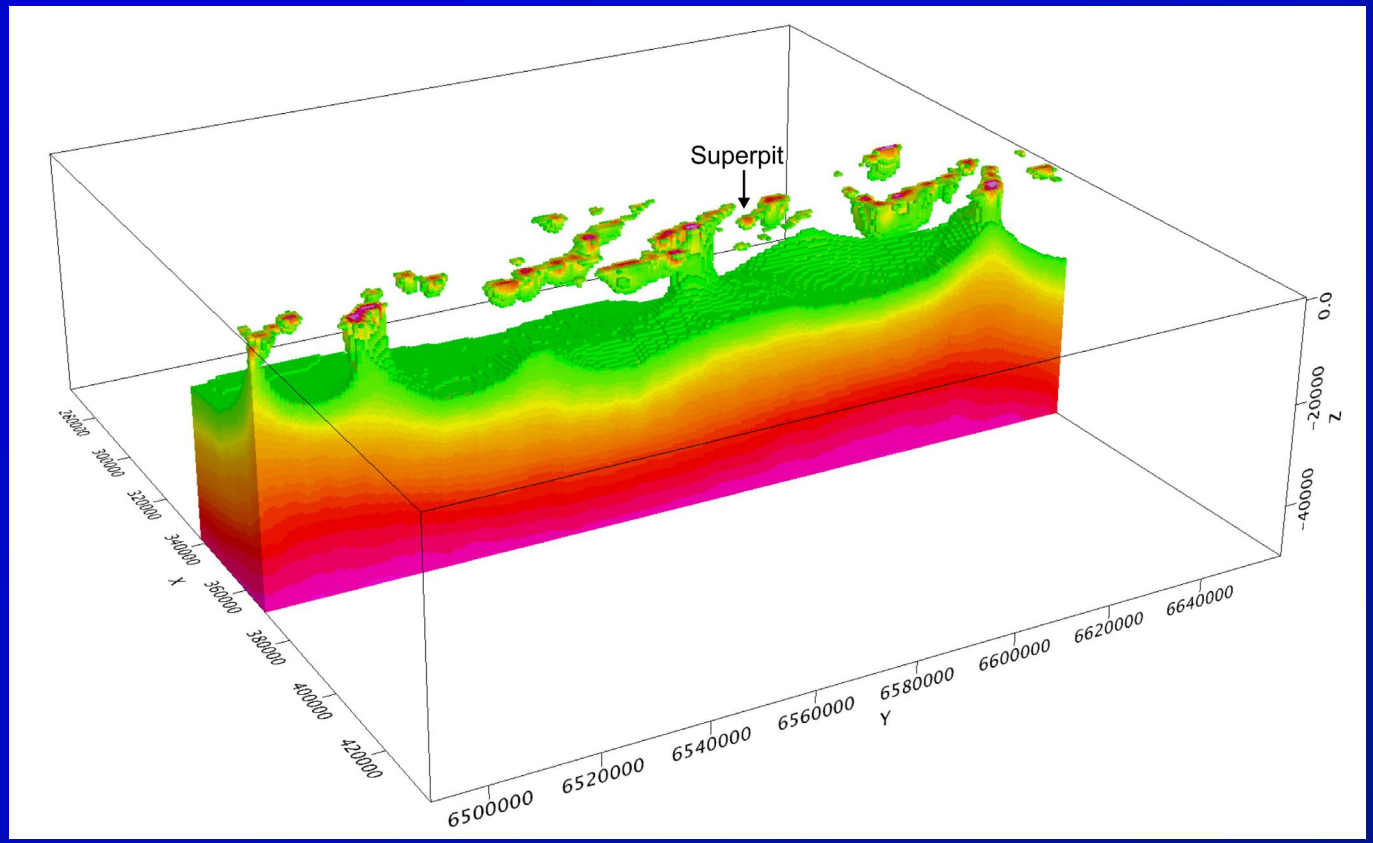


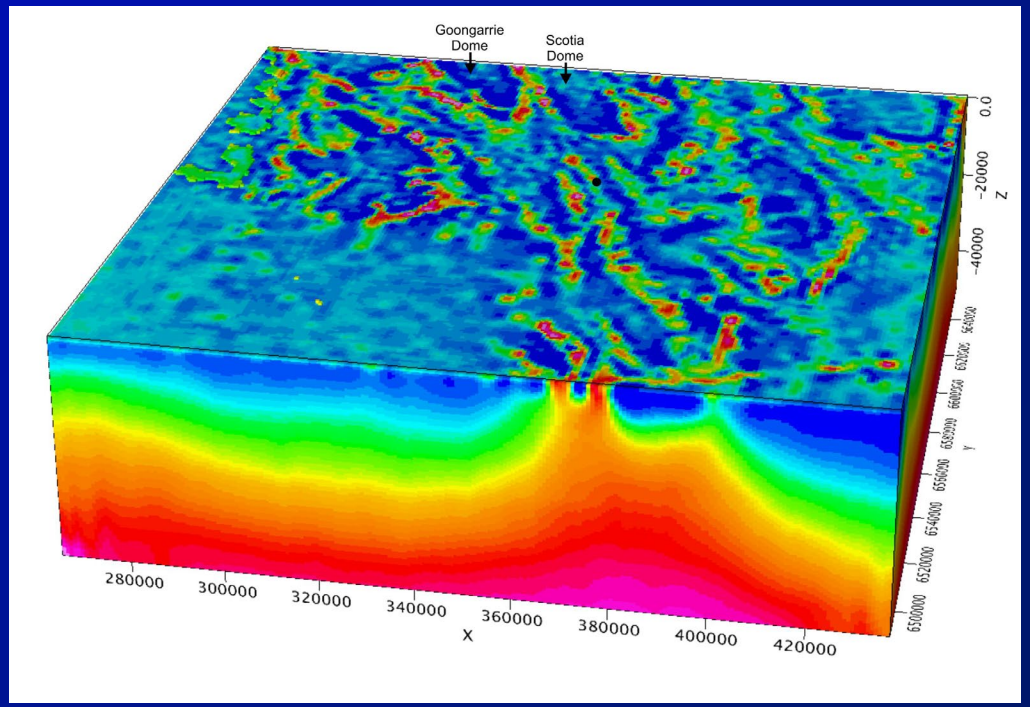


- Lithology interpretation of reflectors constrained by density contrast, but better depth control necessary
- Many mapped volcanic units occur within shallow, <2 km deep, blocks
- Clastic basins are lower density than volcanics
- Decollement reflectors mostly high density

- Smooth 3-D inversion needs regional velocity constraints (N. Hayward, GSC)

3-D Gravity Inversion of Kalgoorlie (One of Many…)





- Many high density units at surface underlain by lower density rocks, e.g. clastics
- High density surface units often extend down to unrealistic depths
- Superpit located where high densities do not extend very deep, <2 km?

Conclusions

- Seismic reflection surveys have potential to image regional-scale 3-D structures
- Interpretation aided by removal of out-of-plane reflections
- Can provide basis for better resolved 3-D gravity inversion
- Need better understanding of origin of seismic reflections
- More offline receivers required for improved location accuracy and even 3-D coverage