

FIG

FIG WORKING WEEK 2017

Helsinki Finland

29 May - 2 June 2017

Presented at the FIG Working Week 2017,  
May 29 - June 2, 2017 in Helsinki, Finland

# International boundaries on a dynamic planet – issues relating to plate tectonics and reference frame changes

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## Overview

- Methods of defining international boundaries by survey
- Plate tectonics
- Impacts of plate tectonics
- Changing reference frames
- Long term maintenance of boundary reference frames
- Case study: Iraq-Kuwait boundary
- Conclusions
- Commission 1 Working Group 1.3 International boundary settlement & demarcation



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## International boundaries defined by survey

- Physical monuments placed and surveyed
  - Monument define the boundary
  - Survey provides documentation
  - Survey assists with maintenance, repair, re-instatement
- Coordinates
  - Coordinates define the boundary
  - Monuments may be placed to make the boundary clearly visible
  - The geodetic datum defining the coordinate reference frame becomes critical



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## Boundaries defined by coordinates

- Historically the reference frame was not always specified (ambiguous)
- If not specified, ambiguity can be hundreds of metres
- If specified, the frame is likely to become obsolete over time
- Reference frames no longer in active use (except for the boundary) will need to be maintained in the long term



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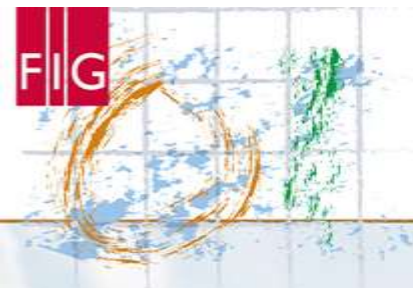
## Plate tectonics

- Theory developed over 20<sup>th</sup> Century
- Validated by geodetic measurements in late 20<sup>th</sup> Century
- Movements are several cm/year = several metres/century



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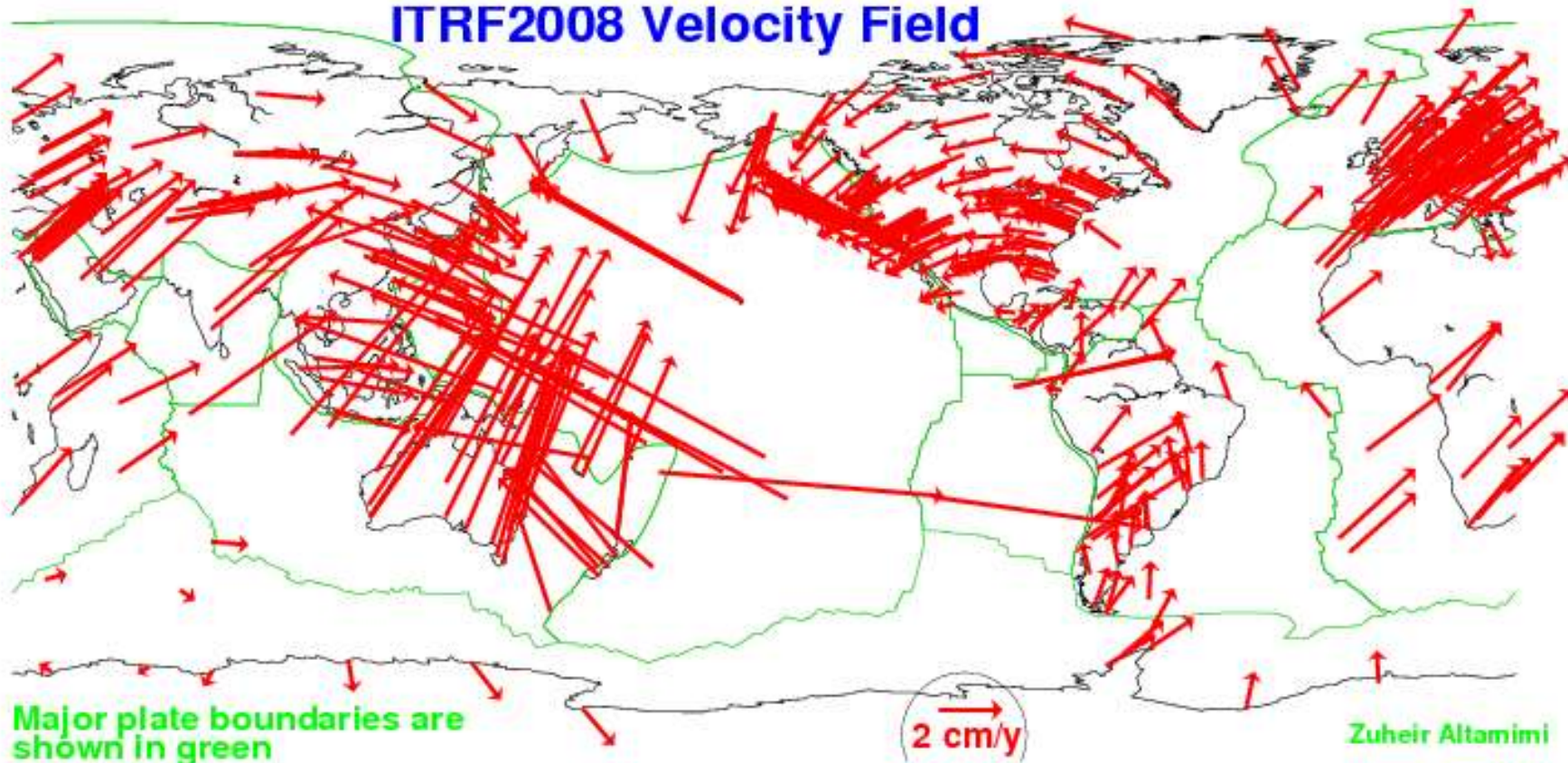
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## ITRF2008 Velocity Field



Major plate boundaries are shown in green

2 cm/y

Zuheir Altamimi



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## Impacts of plate tectonics

- Modern international reference frames
  - have no fixed points on earth
- Meridians & Parallels
  - if defined in terms of global frames, they slowly move across the Earth's surface
- Directions
  - Plates slowly rotating which can affect long times
- Straight lines
  - These may become bent where they cross the plate boundary or major fault lines
- Median lines
  - Will move if land either side of the line are moving differently



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## Changing reference frames

- Global frames (WGS84 & ITRFs) are periodically updated
- National frames are changed from time to time
  - Updated for new technology & plate tectonics
- Some national or regional frames moving to a “dynamic” model
  - Coordinates continuously change as the Earth moves



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## Long term maintenance of boundary reference frames

- If defined by ITRF at an epoch, then maintained through transformations
- If defined in terms of the coordinates of a specified origin mark – then maintenance of mark becomes crucial for both countries
  - May be an issue if the mark is located in only one country
- If defined by coordinates of a set of marks then maintenance of the set of marks becomes crucial
  - Ideally some marks will be located in each country
- Even if defined by marks, transformations can back up the definition
  - Over long periods, a sequence of accurate transformations back to the original reference frame will be required.



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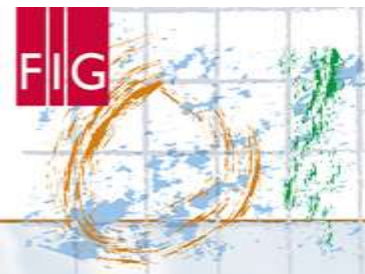
## Case Study – Iraq-Kuwait Boundary

- Coordinates are definitive
  - Monuments (pillars) placed on correct coordinates
- Independent plate fixed datum – Iraq Kuwait Boundary Datum 1992
  - Not precisely related to ITRF  $\pm$  few metres
- Boundary moves with the plate – and with the pillars
  - Datum at risk (only 1 or 2 of definitive datum stations still available)
  - Dependency on primary control stations to “reverse-engineer” the datum
  - Some primary control stations also lost
- Maintenance necessary to protect the boundary in the long term



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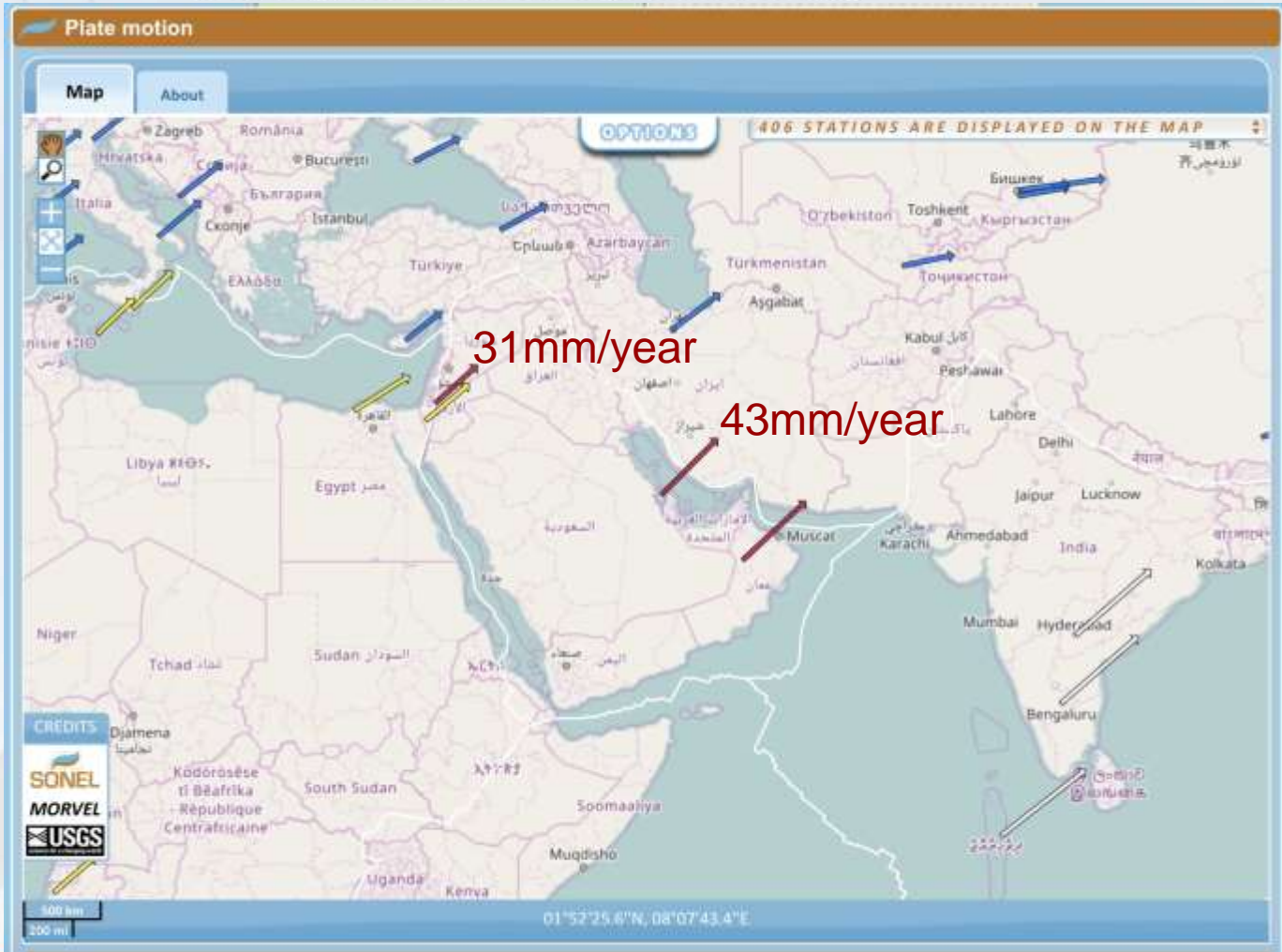


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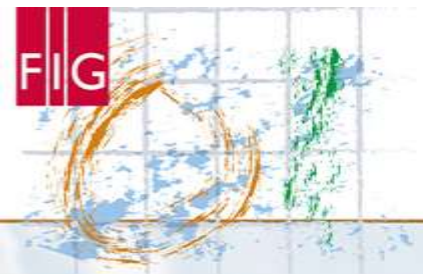
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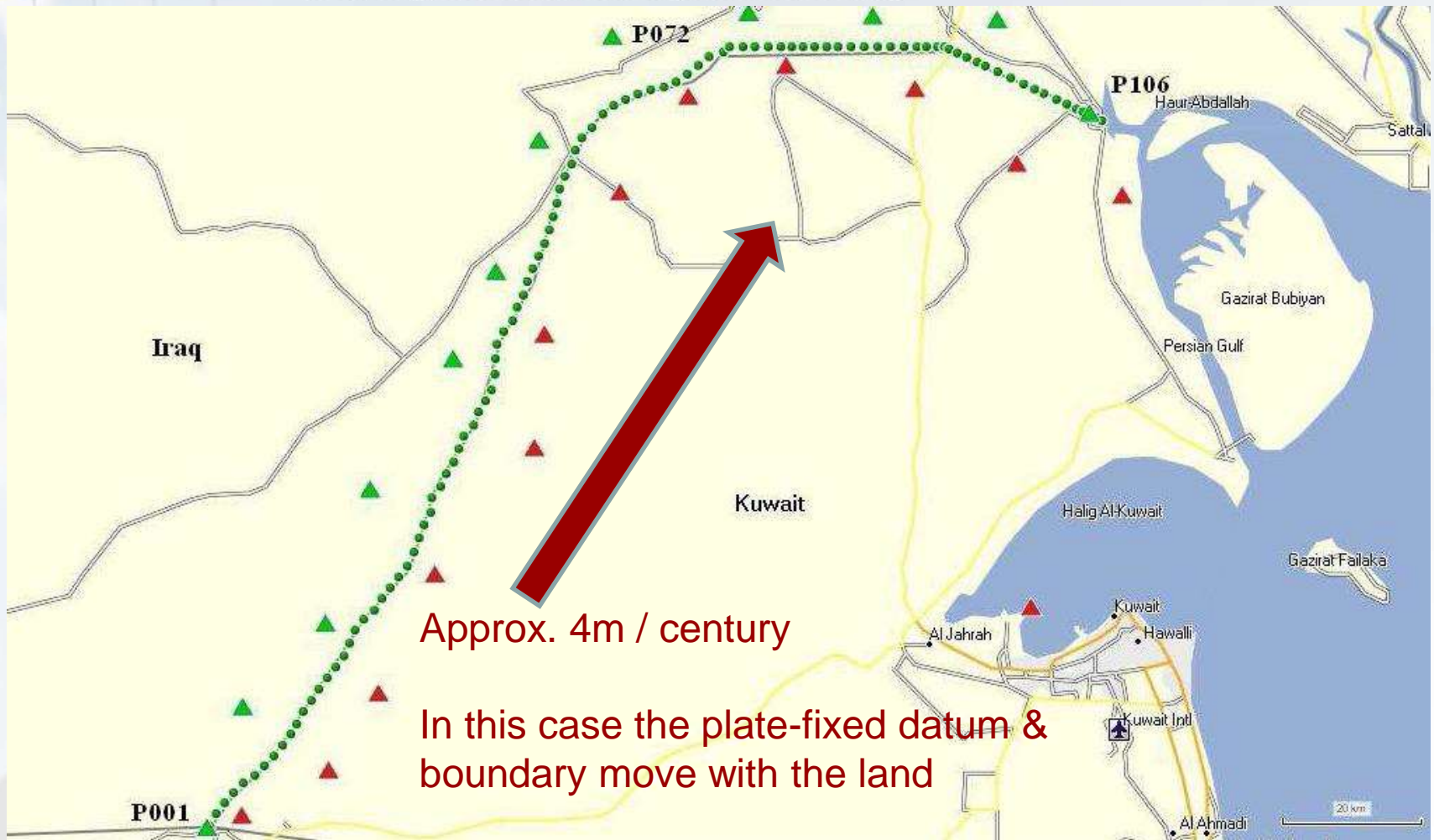


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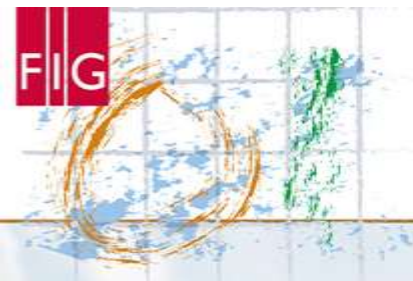
## Potential changes

- The Iraq Kuwait boundary coordinates defined in terms of a plate fixed datum
- **Therefore no change over time in sovereignty of land or resources**
- However if the boundary had been defined by fixed ITRF coordinates
  - Survey accuracy standard for boundary pillar placement of 200mm would have been exceeded by tectonic movement in just 5 years
  - Since 1992 survey (25 years), land and resources would have moved 1m relative to the boundary
  - Value of oil in Rumaila field is approximately US\$10M per metre in the north-south direction



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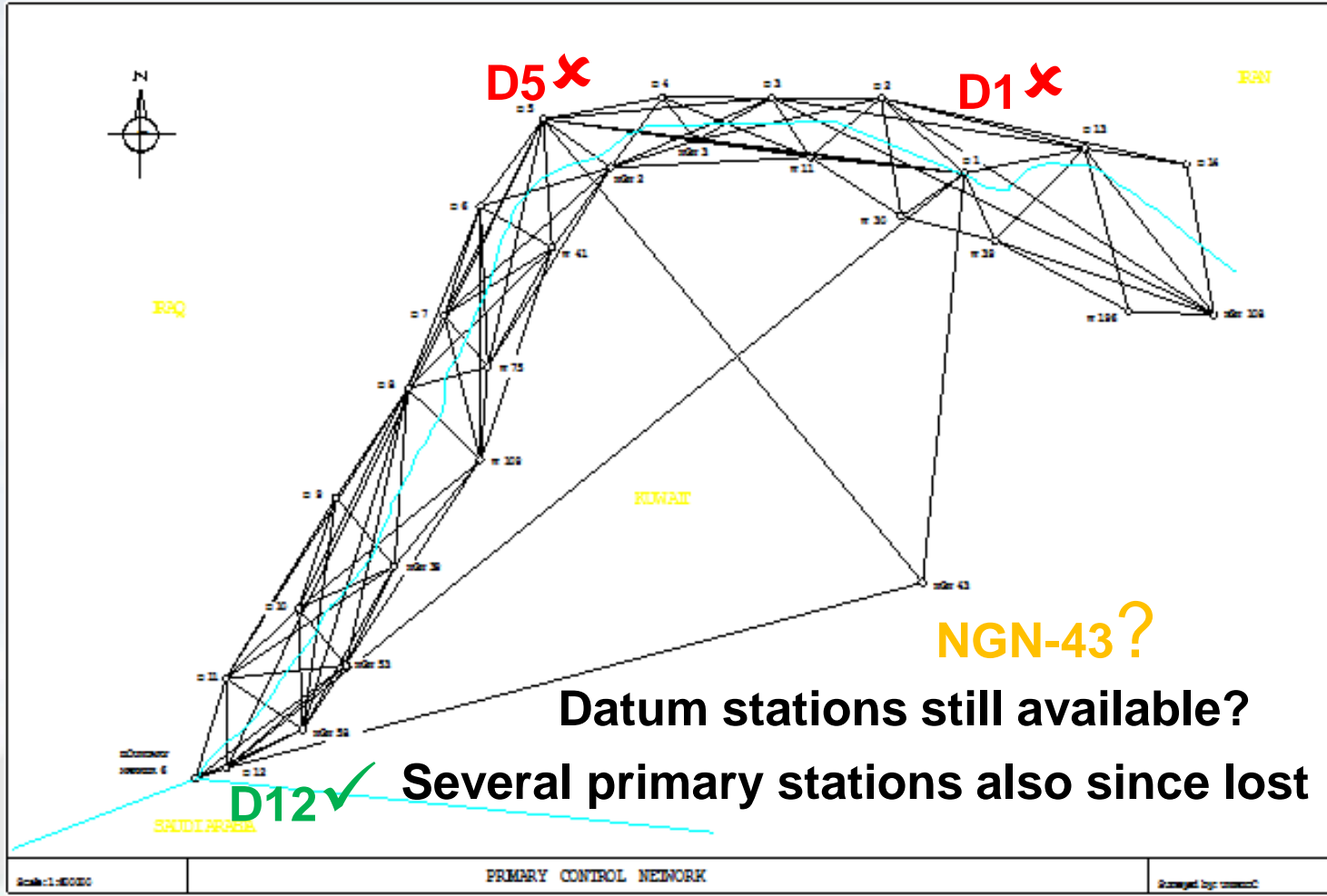


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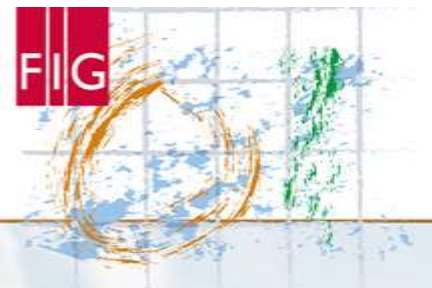
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## Conclusions

- Geodetic survey often used to define & maintain international boundaries
  - Boundary is then dependent on maintenance of the geodetic datum
- Geodetic datums also require maintenance
  - Affected by tectonic plate motion
  - Datums are updated more frequently than international boundaries
- Boundary negotiations should consider:
  - Definition of geodetic datum
  - Impact of changes in geodetic datum
  - Impact on the boundary of tectonic movement
    - Does the boundary moves with the land or with the coordinates?



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## Working Group 1.3

### International boundary settlement & demarcation

- Propose a supplement to FIG Publication 59 International Boundary Making
- Focus on geodetic and tectonic issues impacting on boundaries in the long term



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