STUDS
a widespread, much misunderstood rail defect

Dr Stuart L Grassie
Stuart Grassie Engineering Ltd
Tel: +44 1223 522475
Mobile: +44 7803 290252

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acknowledgements

- co-workers on project with TfNSW / Sydney Trains / RailCorp
  - Malcolm Kerr
  - Andrew Wilson
  - David Cooper (ASA)

  basis for most of the work discussed here
- University of Sheffield
  - David Fletcher

  project with SBB/CFF from which some metallurgical analysis is shown here, and earlier work with Tubelines (LU)
- original work with Tubelines (2006-2007)

scope

- Historical background
  - what are “squats”, “studs”, “rolling contact fatigue”?
  - why should we be bothered?
- RCF
  - appearance, initiation, development and consequences
  - treatment
    - what is done?
    - is it successful?
- “studs”
  - appearance, initiation, development and consequences
  - treatments: common and unusual
- conclusions and further work

NB Much of what is shown here is the work of others.

historical background: squats

- from 1970s, mainly UK and Japan
  - British Rail Research were a pioneer in RCF research
  - proposed in early 1980s that routine reprofiling would be a good treatment
- relatively high speed passenger lines
  - WCML in UK, tests sites at Rugby and elsewhere
- high traction locos
- substantial increase in rail breaks
- considered to be rolling contact fatigue (RCF)
  - metallurgy (mainly BRR: PC, MBPA)
  - mechanics (mainly CUED: KLJ)
- well understood and reliable treatments developed and implemented by mid-1990s

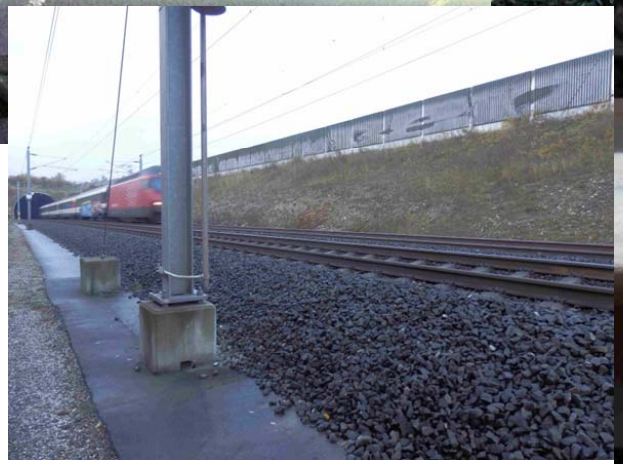
historical background: RCF general

- RCF in a different manifestation to squats
  - gauge corner cracking (GCC) / head checking (HC)
  - prevalent on so-called “heavy haul” railways
- noted initially in late ‘70s / early ‘80s
  - costs of rail renewal in Canada in early 80s similar from side wear and all types of fatigue (Mike Roney, CPR, 1982)
- also gave rise to broken rails
- treatments developed and implemented very quickly
  - “Correct” treatment proposed by BRR in early ‘80s, implemented 20 years later (long after implementation on haevy haul lines)
    - Is heavy haul traffic more valuable than people?
- RCF is now common on almost every type of railway system

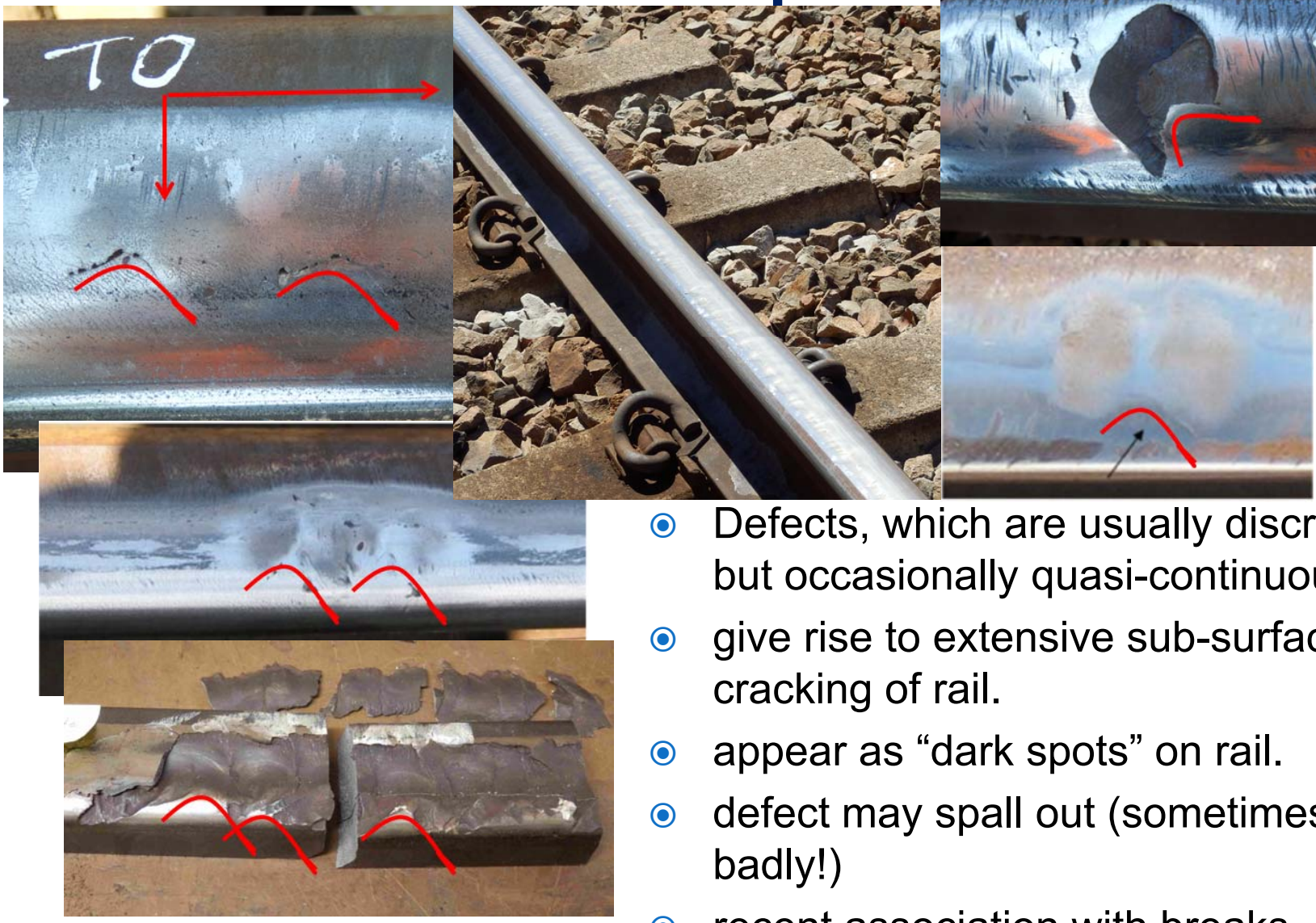
historical background: studs

- first noted about 15 years ago in NSW, on freight lines, subsequently on many other railway systems
  - not just high speed passenger lines
- superficial appearance very similar to that of squats
  - classified universally as squats
  - treated as squats i.e. as defects that could potentially break a rail (this is still almost universally the case)
- considerable research worldwide
  - *almost* universal assumption that these are squats
- proposed by SLG and colleagues that these were <u>not</u> squats:
  - JRRT paper from 2012, presented originally at CM2009
  - introduced different nomenclature to avoid confusion
    - less imaginative contribution to etymology than “squats”

studs



studs: further examples



- Defects, which are usually discrete but occasionally quasi-continuous
- give rise to extensive sub-surface cracking of rail.
- appear as “dark spots” on rail.
- defect may spall out (sometimes badly!)
- <u>recent</u> association with breaks

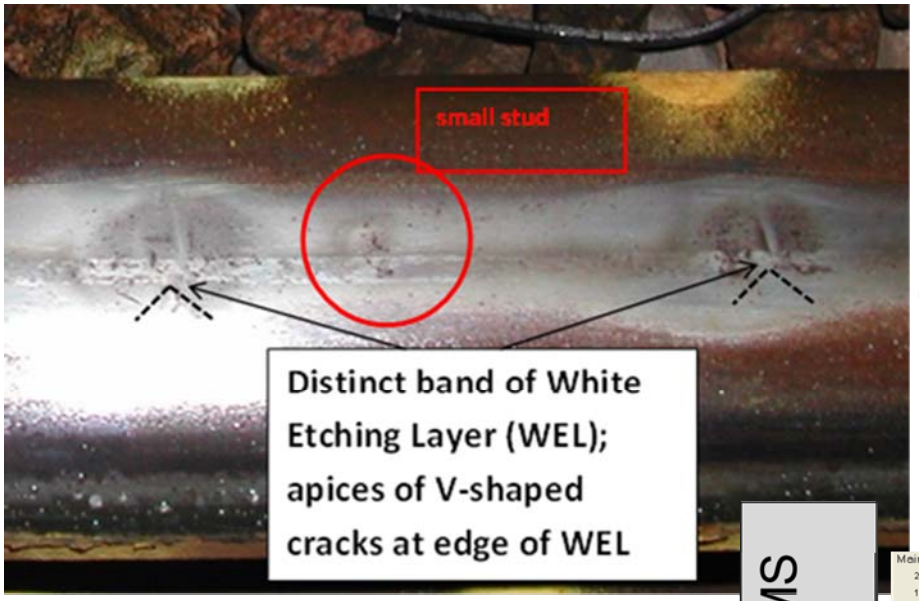
initiation

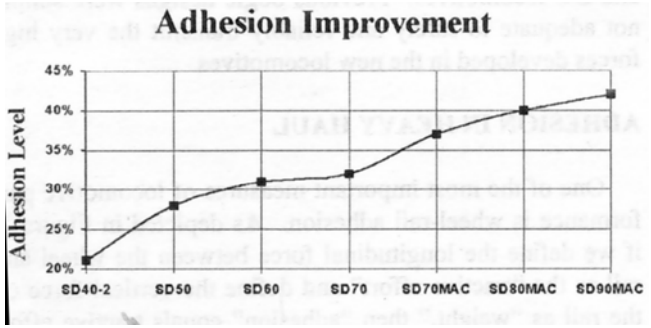
- initial hypothesis was that a small crack is initiated from locomotive wheelslip
  - slip creates martensitic white etching layer (WEL)
  - by assumption, strip of WEL is formed along the rail
  - differential contraction gives small crack

The hypothesis is essentially a forensic investigation of available evidence from a multitude of sources.

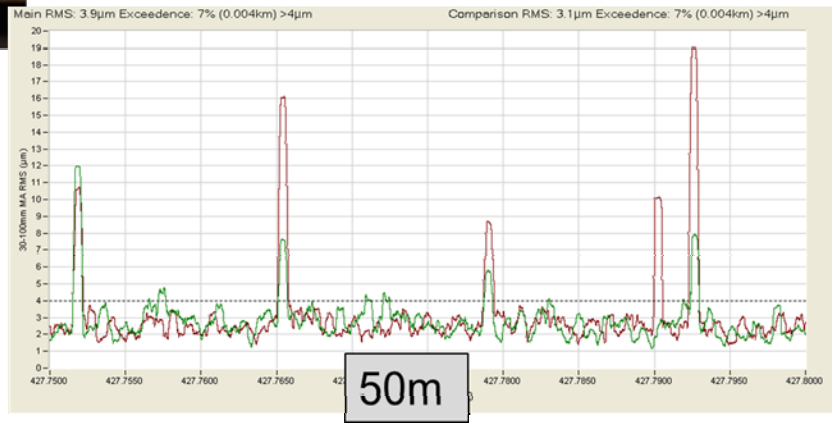
- recent work from VA suggests that a very narrow band of high residual tensile stress may be responsible

evidence re wheelslip, traction, defects on opposite rails



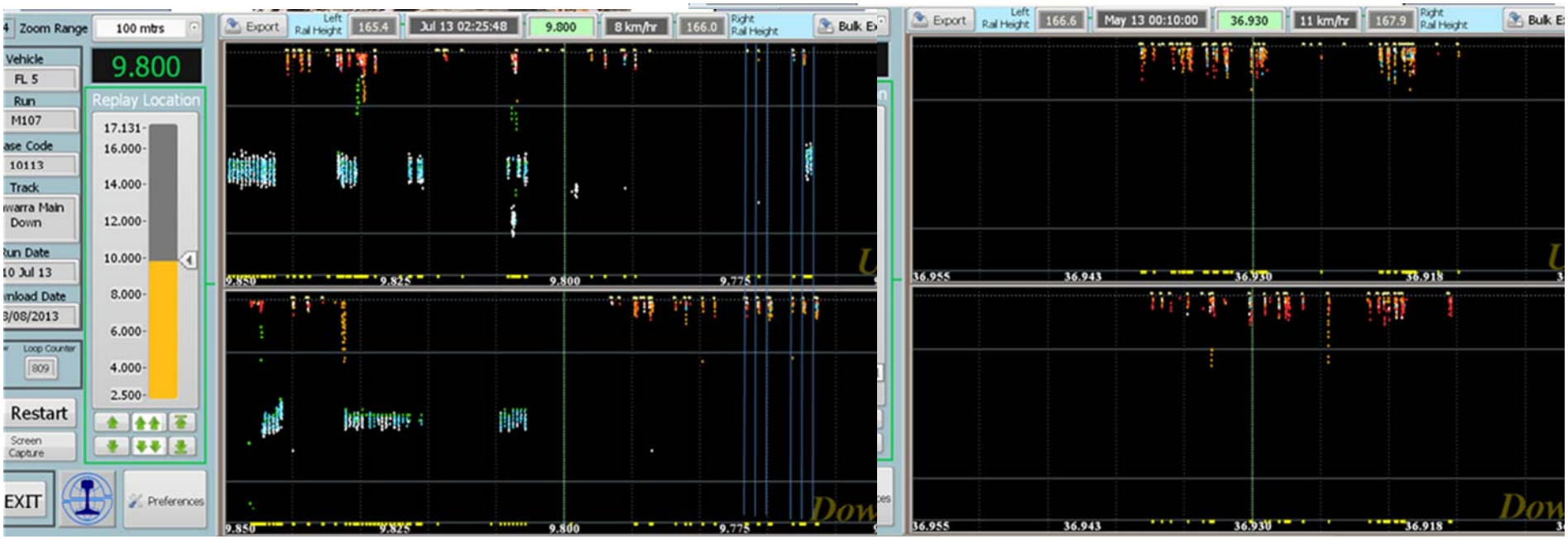


0.020mm RMS full scale



- strong association with software-controlled traction systems
  - circumstantial evidence from London Underground (2007)
    - studs: Piccadilly, Northern, Central
    - no studs: other lines

evidence from ultrasonic test train

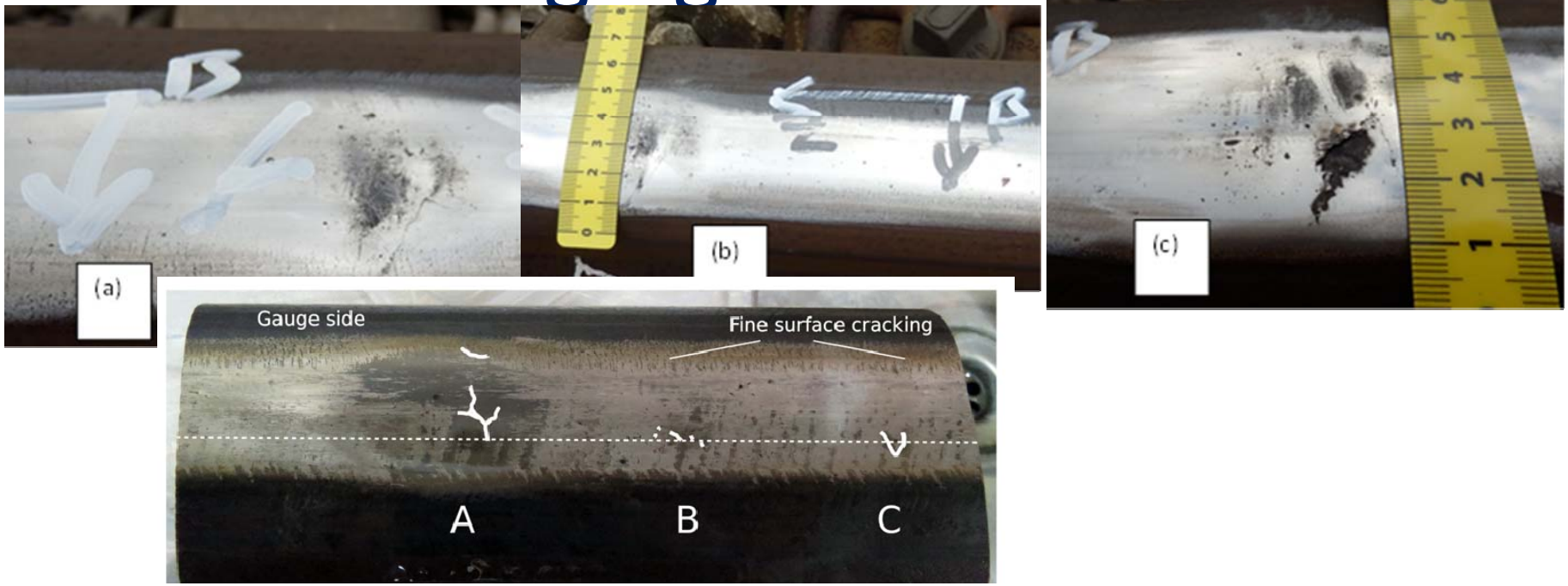


- replays from ultrasonic test train (NSW)
  - characteristic signal has been identified from studs
  - tendency for studs to be opposite one another
  - tendency also in some locations for defects to be at axle spacing of power cars (Co-Co locos on LHS)

studs and wheelslip damage

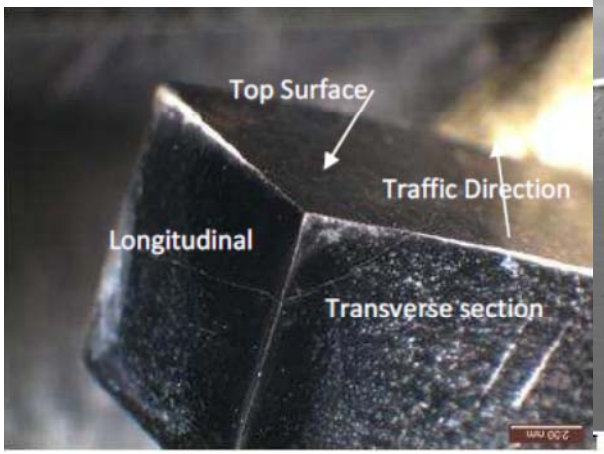
- direct association of defects with WEL (NSW)
  - wheelslip damage on down (high) rail
  - subsequent defects (screen on right for down rail)
  - also new closures, with no WEL and no defects

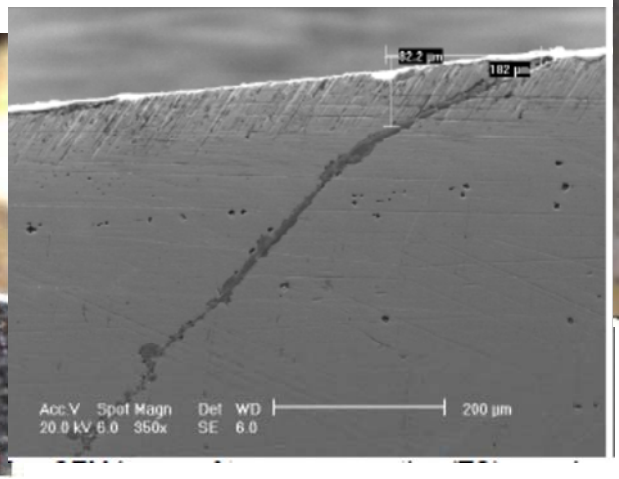
wheelslip: crack mouth at constant distance from gauge face

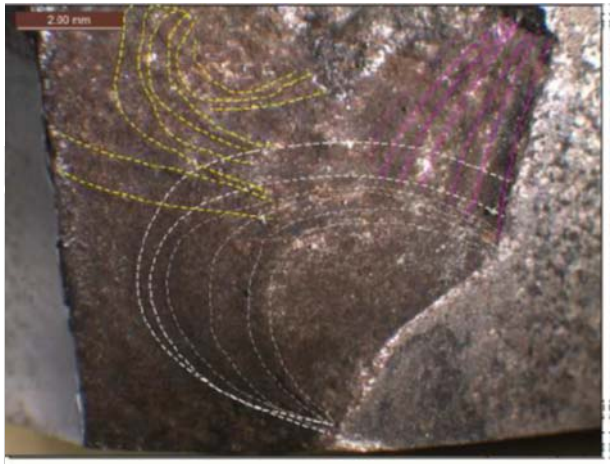


- direct association of defects with WEL
- constant distance of small defects from gauge face:
  - 30mm in (a), (b) and (c), all at same site
  - defects A, B, C (below) well aligned

growth into rail (UQ)

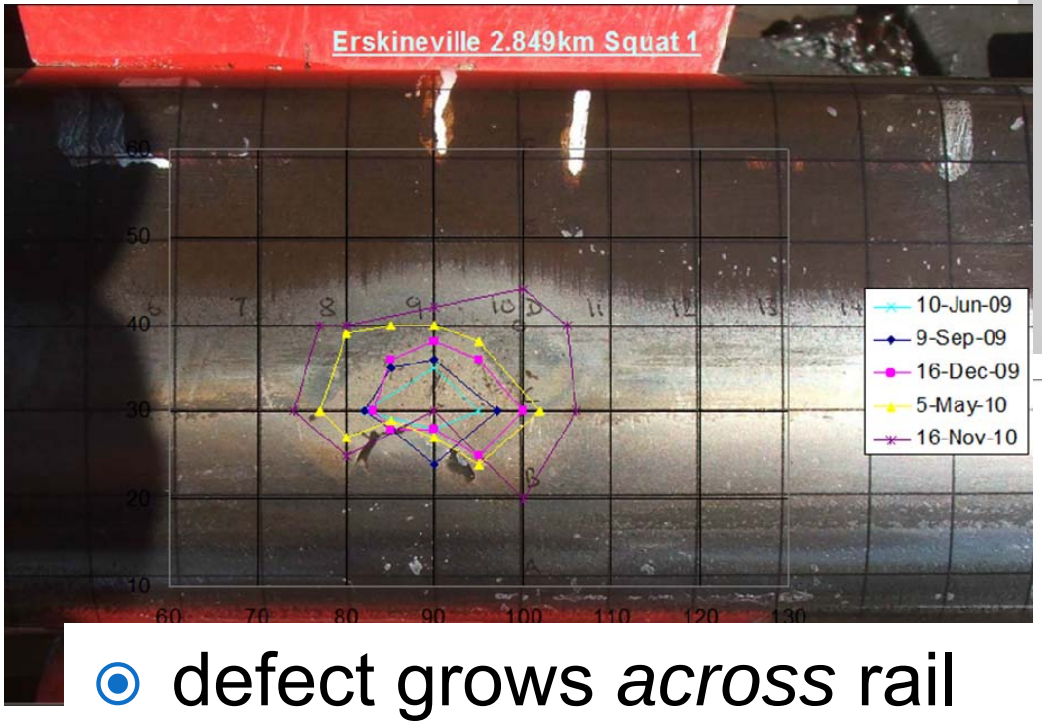


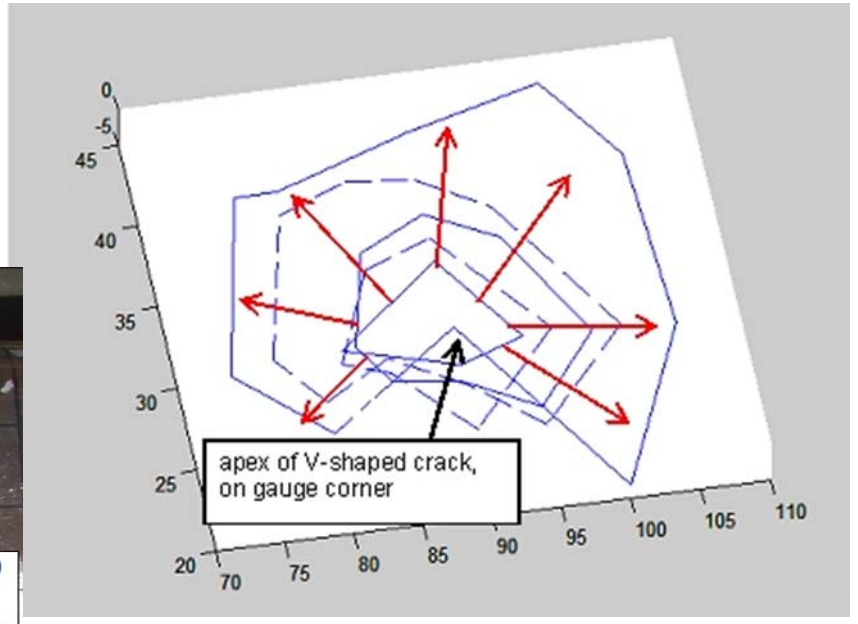


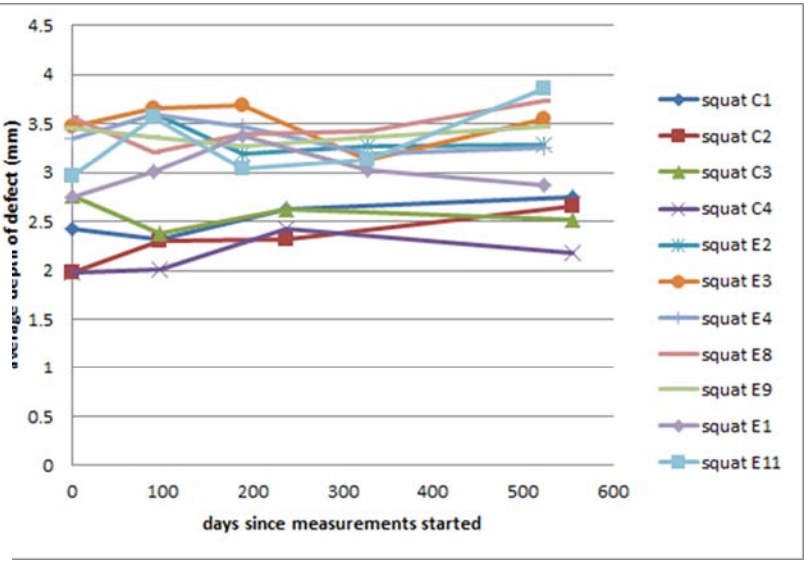


- Initial growth into rail at angle of roughly 20°
- Several patterns of growth rings
  - "growth rings" are <u>not</u> characteristic of RCF

measurements *in situ* (RailCorp)



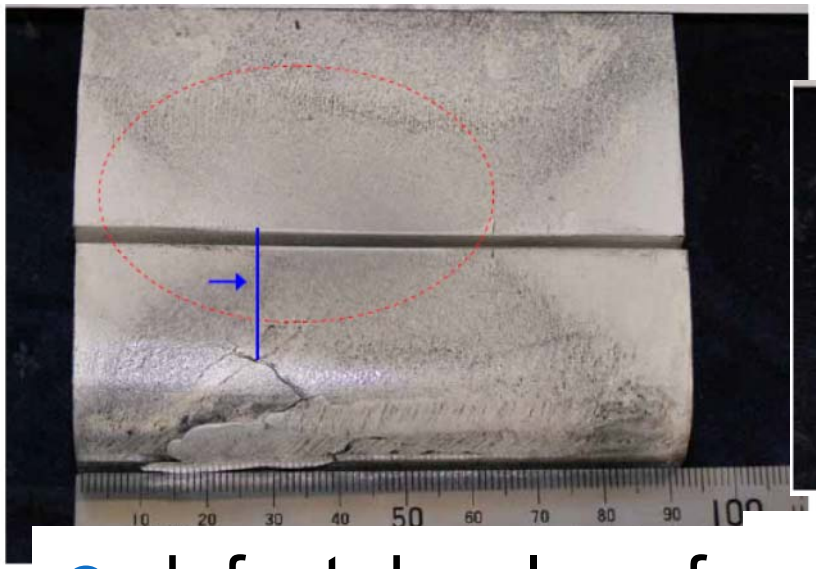




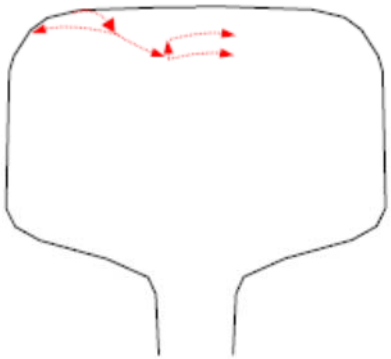
- defect grows *across* rail and at roughly constant depth with time
- measurements suggest growth out from V-crack

Approx 25MGT p.a. of traffic

propagation (IRT work for RailCorp)



- defect develops from gauge to field
- grows at roughly constant depth beneath surface



forces responsible for propagation?

- apex of the V-shaped crack points to outside of the curve on both rails
- defect develops towards outside of curve
  - force on surface of rail has been to inside of curve

studs and squats: how quickly do they develop?

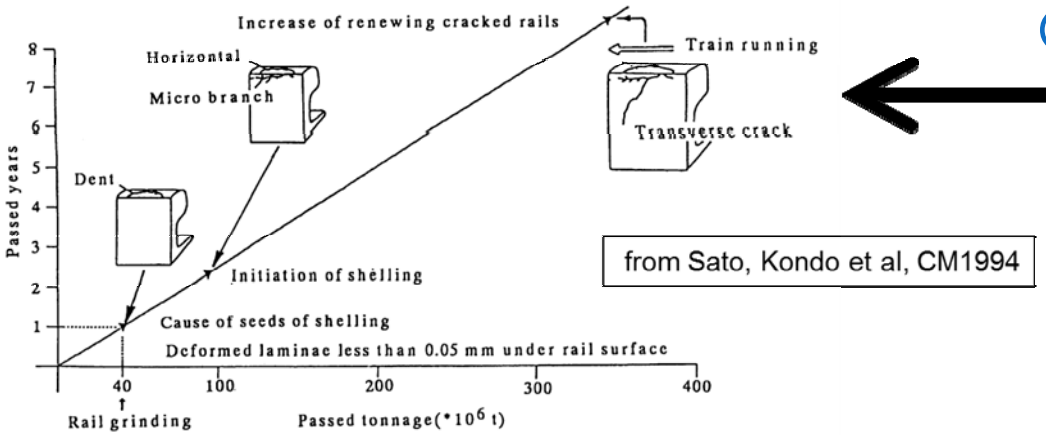
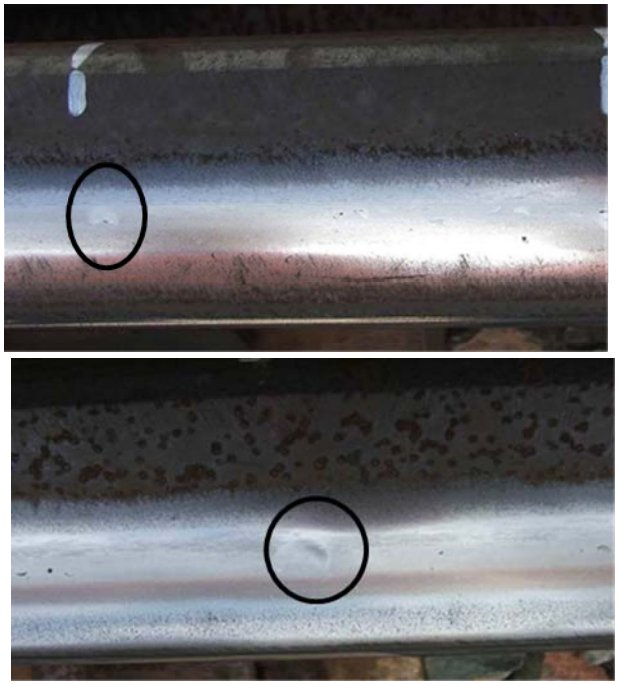


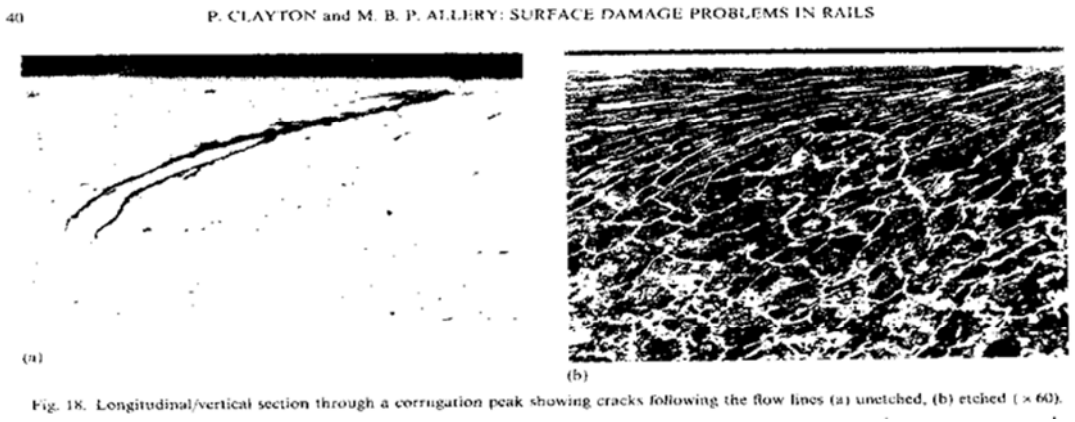
Fig. 6. Cause and growth of shelling depending on passed tonnage.

- Squats (Japan)
  - **100MGT to 5mm depth**

- Studs (RailCorp)
  - **6MGT from just perceptible to 2.2mm depth**

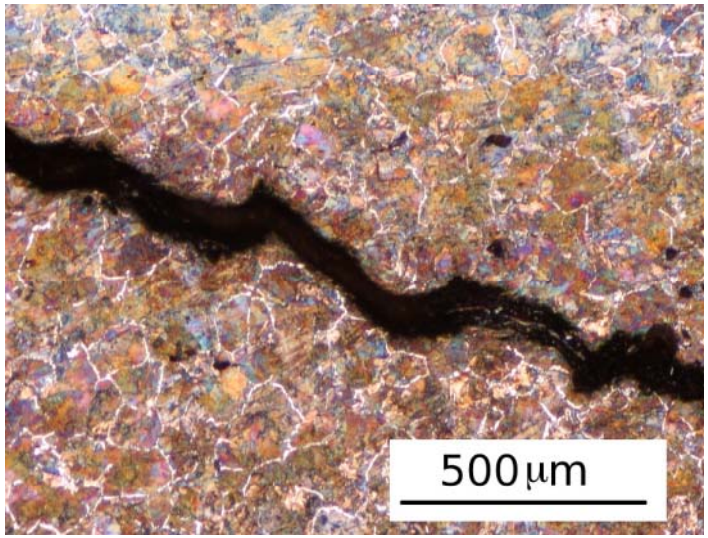


cross section

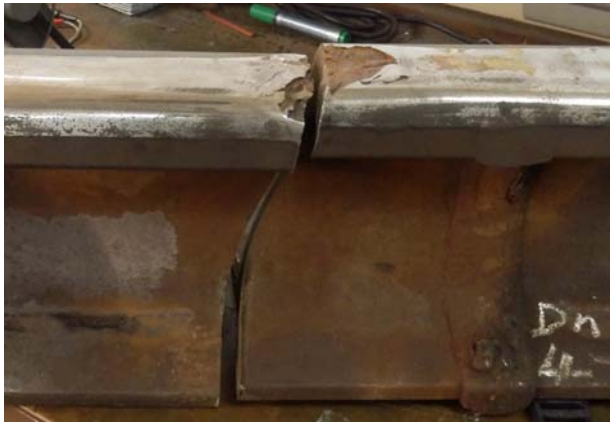


- RCF
  - shearing of surface layer
  - “exhaustion of ductility”

- Studs (for LUL)
  - jagged cracks
  - can develop without shearing of surface layer
  - don‘t develop along ferrite layer



broken rails
(typical of at least two railway systems)



- In all cases, there is RCF/GCC as well as a stud (or series of studs)
  - the RCF has “turned down” to give the transverse defect
  - dynamic load from the stud causes break in that location

How are studs usually treated?

If considered to be squats:

DB Mobility Networks Logistics

Squats – minimum action rules

Innotrack guideline D4.2.6

Recommendation of, and scientific basis for minimum action rules and maintenance limits

Current Minimum Actions for Squats - DB

Length	Depth	Emergency action	Timescale
L > 30mm	or: > 20mm	single squat: 120km/h (160km/h) with clamp (different kind) multiple squats or squat in conjunction with Head Checks: 20km/h	Immediately
10mm< L ≤ 30mm	or 10mm< Depth ≤ 20mm	single squat: repair weld multiple squats: rerail	Before next inspection
<10mm	all	repair weld	

What is being done in NSW?

- Actions based on defects not being squats
- planned rerailing to reduce “untestable” rail
  - 20km p.a. specifically for studs
- reprofiling
  - limited possibilities because defects grow deeply (3-6mm) and fast
  - reprofile to remove GCC to reduce risk of breaks
- Reversion to “default” SC rail from “default” HH rail
  - following evidence that studs are less common in SC rail
- Improved use of replays from ultrasonic train for detection
- Cooperative research with other railway systems and universities

Is the alternative strategy OK?

- Broken rails
  - these appear to have occurred primarily from RCF
  - previous conclusion re relatively benign nature of studs still holds
- mix of pragmatism and planning in the absence of a full understanding
- complements the approach taken by LU

NB Requires acceptance that these defects are not squats!

conclusions

- RCF
  - dangerous: can cause rail breaks if untreated
  - develops initially relatively slowly
  - well understood and treatments available
- studs
  - more benign than RCF
    - do not themselves develop into TDs
  - develop relatively quickly
  - poorly understood, few treatments available but extremely widespread
  - problem has existed for more than a decade
  - area is still open for some intelligent research
  - a pragmatic approach can in the meantime ensure both safety and savings