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What do we know about the Newdigate, Surrey earthquakes?

Posted on 12th August 2018 by [Professor David Smythe](https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/?author=1) (<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/?author=1>)

The short answer is, not a lot. However, I shall try to summarise what is known so far, leaning on input from experts including the British Geological Survey (BGS), Dr Steve Hicks (Southampton University) and the two Stuarts from Edinburgh University (Professor Haszeldine and Dr Gilfillan). My own contribution, presented below, is to tie in the earthquakes to the subsurface faults in the locality.

What?

A sequence of 11 earthquakes began in Surrey on 2018 April 1 (I am pedantically using the descending date-time order preferred by seismologists and astronomers, avoiding the ambiguity of 1/4/18, which is rendered illogically as 4/1/18 in America-speak).

Date	Lon	Lat	Mag
2018-07-18	-0.247	51.157	0.9
2018-07-18	-0.239	51.158	2.4
2018-07-18	-0.250	51.162	0.4
2018-07-18	-0.250	51.162	1.9
2018-07-10	-0.233	51.171	1.9
2018-07-05	-0.246	51.163	3.0
2018-06-29	-0.264	51.178	2.4
2018-06-27	-0.238	51.153	2.6
2018-04-01	-0.267	51.140	1.8
2018-04-01	-0.256	51.150	1.7
2018-04-01	-0.272	51.139	2.7

(<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/wp-content/uploads/2018/08/BGS-eq-list-border.jpg>)

Eleven earthquakes at Newdigate recorded by the BGS between 2018 April 1 and 2018 August 12. The latest one was on July 18. Mag is the local magnitude (click to enlarge).

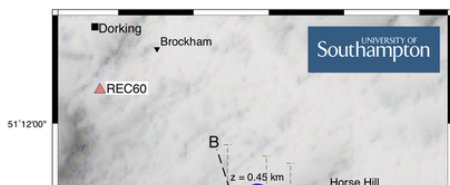
(<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/wp-content/uploads/2018/08/BGS-eq-list-border.jpg>)

Where?

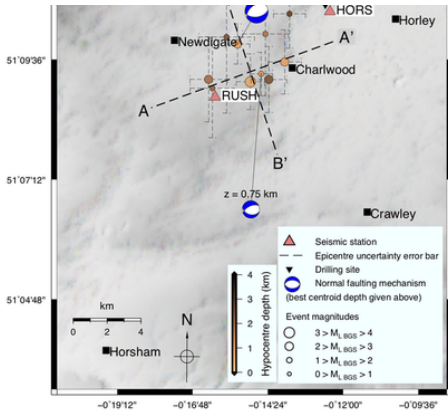
The first quakes, a magnitude 2.7 plus two small aftershocks, were poorly located. The BGS

(<https://web.archive.org/web/20230321203127/http://www.earthquakes.bgs.ac.uk/research/SurreyEarthquakes2018.html>) installed two local seismometers in mid July; these recorded the four events of 2018 July 18. Since then the BGS has installed a further three seismometers, but there have been no further events to date (2018 Aug 12).

Steve Hicks has [relocated](https://web.archive.org/web/20230321203127/https://sphicks.weebly.com/2018-surrey-uk-earthquakes.html) (<https://web.archive.org/web/20230321203127/https://sphicks.weebly.com/2018-surrey-uk-earthquakes.html>) the epicentres. Here is the result of one of his two methods; this one uses a Bayesian relocation method, which yields a better depth estimate, but it is said to be somewhat experimental.



(<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/wp-content/uploads/2018/08/surreyquakesbayeslocmapshicks.png>)

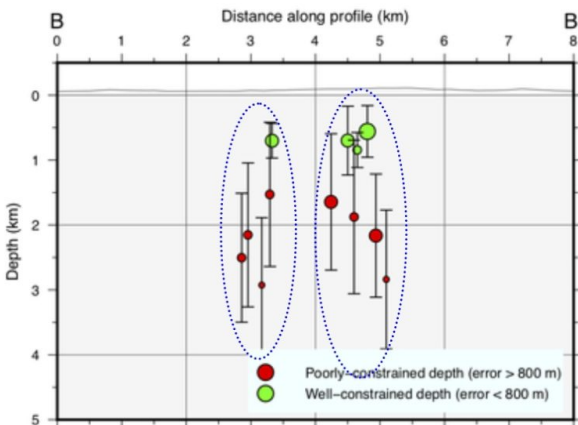


Relocation of the earthquakes between Newdigate and Charlwood by Steve Hicks. Profile BB' is discussed below ([click to enlarge](#)).

The nearby seismometers are REC60, a private seismometer belonging to the Raspberry Shake [worldwide network](https://web.archive.org/web/20230321203127/https://raspberrysshake.org/community/station-view/) (<https://web.archive.org/web/20230321203127/https://raspberrysshake.org/community/station-view/>), and the two original temporary stations installed by the BGS; HORS and RUSH. The two 'beach balls' indicate solutions with depths of 450 m and 750 m, which are unusually shallow for natural earthquakes, but which lie within the operating depths of the wellbores at Brockham and Horse Hill (shown by the inverted black triangles). The line of intersection of the four sectors on each beach ball indicates the

trend of the calculated fault which slipped to produce the tremor in each case. Their alignment with a white sector uppermost indicates normal faulting. The calculated fault trends are ENE-WSW and E-W, respectively, which accords well with the known trend of deep faults. A comparison of the profile BB' with available seismic reflection data is shown below.

Profile BB' indicates the depths of the hypocentres, projected onto this vertical plane. The hypocentres fall into two groups, which I have highlighted in Hicks's diagram below with blue ellipses.



(<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/wp-content/uploads/2018/08/surreyquakesbayes-profile-BB-two-groups.jpg>)

Hicks's profile BB' showing the earthquakes falling into two groups ([click to enlarge](#)).

(<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/wp-content/uploads/2018/08/surreyquakesbayes-profile-BB-two-groups.jpg>)

The four best-determined locations, shown in green, lie at 600 to 900 m below sea level. This information is combined with the geology in a section below.

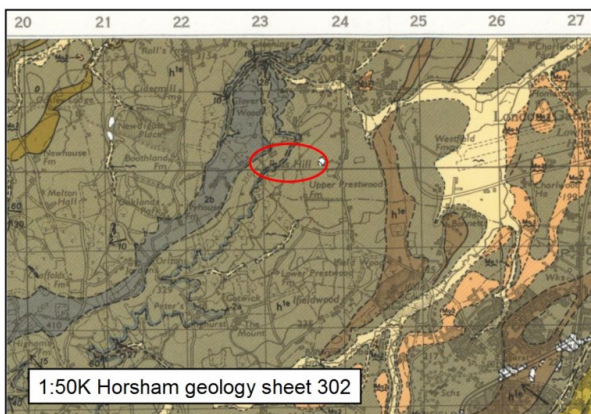
Denial by UKOG

Steve Sanderson of UK Oil and Gas (UKOG) is on record on [BBC Radio Surrey](https://web.archive.org/web/20230321203127/https://www.youtube.com/watch?v=wPrp1QBZZUk&feature=youtu.be) (<https://web.archive.org/web/20230321203127/https://www.youtube.com/watch?v=wPrp1QBZZUk&feature=youtu.be>) on August 7 as saying that:

"the data that I've looked at shows that these tremors were actually clustered around quite a large fault which comes to the surface around Russ Hill" [recording 2:03 to 2:14].

So what is the evidence for this fault? I have examined the BGS geology maps for the district around Russ Hill.

Firstly, here is the printed **Horsham sheet 302** (<https://web.archive.org/web/20230321203127/http://www.largeimages.bgs.ac.uk/iip/mapsportal.html?id=1001794>) at 1:50,000 scale.

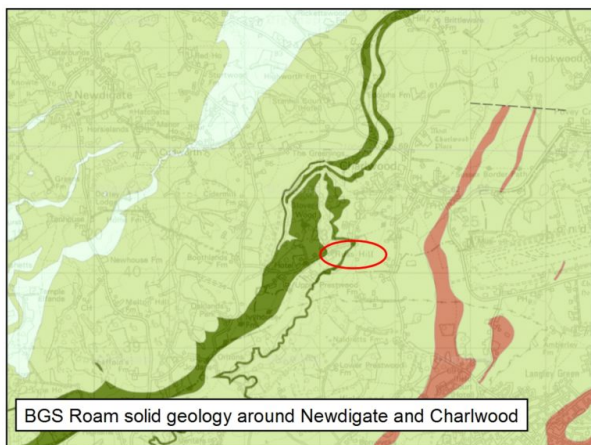


(<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/wp-content/uploads/2018/08/horsham-geol-russ-hill.jpg>)

BGS 1:50K Horsham solid and drift geology sheet 302. Russ Hill is highlighted by the red ellipse (click to enlarge).

(<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/wp-content/uploads/2018/08/horsham-geol-russ-hill.jpg>)

I have circled Russ Hill in the map above. Solid geology is in dark shades, superficial deposits in light tan and buff. I see no evidence for outcropping faults. Just in case this map, from 1972, had been updated, I also looked at the online BGS Roam data (available to research institutions through **EDINA Digimap** (<https://web.archive.org/web/20230321203127/https://digimap.edina.ac.uk/>)). This map shows solid geology only.



(<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/wp-content/uploads/2018/08/BGS-roam-solid-geol-russ-hill.jpg>)

BGS Roam solid geology (online) with Russ Hill highlighted by the red ellipse (click to enlarge).

Once again, no faults are shown anywhere near Russ Hill (circled in red).

I therefore challenge Mr Sanderson to produce evidence for his alleged "large fault". If he cannot do so, the

impression seems to be left that he is once more prepared to come out with **any old nonsense** (<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/?p=468>) in order to defend his company and support the share price.

Denial by Angus Energy

Angus operates the Brockham field near Dorking; it lies between 6 and 10 km north of the earthquake epicentres. Mr Andrew Hollis, Angus chief geologist, is quoted as follows:

"The earth's natural geological fault lines in the deep subsurface at Brockham run east - west. However, the epicentres of these earthquakes were to the south of the site. Therefore it is physically impossible for

the Brockham field to create an earthquake." [Advertorial in Surrey Live (<https://web.archive.org/web/20230321203127/https://www.getsurrey.co.uk/special-features/local-oil-company-angus-energy-14988544>), 2018 Aug 6].

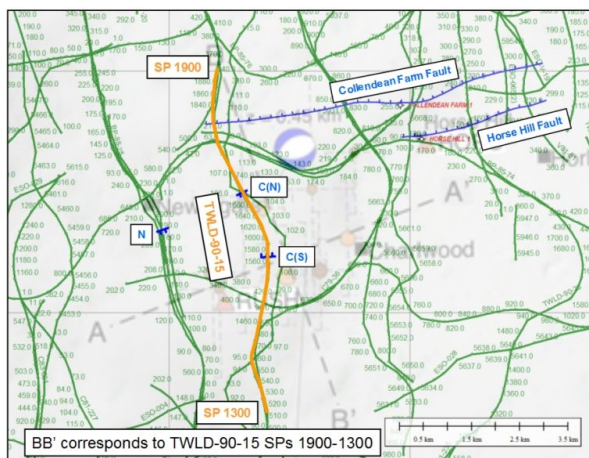
Mr Paul Vonk, managing director of Angus, said at the [meeting of Surrey County Council](https://web.archive.org/web/20230321203127/https://drillordrop.com/2018/08/08/live-updates-decision-meeting-on-brockham-oil-well-drilled-against-council-advice/) (<https://web.archive.org/web/20230321203127/https://drillordrop.com/2018/08/08/live-updates-decision-meeting-on-brockham-oil-well-drilled-against-council-advice/>) on 2018 Aug 8 which approved the retrospective planning application for the unauthorised sidetrack well at Brockham:

"... it is scientifically impossible for Brockham oil field to cause the earthquakes. There is no physical connection between the fault at Brockham and the earthquake area. The mostly likely cause is natural."

The supposed physical impossibility of a link between underground drilling or injection activity and triggering of earthquakes, averred so dogmatically by these two gentlemen, is contradicted by evidence from the USA, discussed below.

Subsurface faulting

The map below shows the available 2D seismic database (<https://web.archive.org/web/20230321203127/https://ukogl.org.uk/ukogl-interactive-map/>) (green lines) superimposed on Hick's map. Most of the seismic reflection data date from the early 1980s; there are no 3D surveys here. Blue lines with teeth on the downthrown side mark normal faults. The Collendean Farm Fault and the Horse Hill Fault come from my [analysis](https://web.archive.org/web/20230321203127/http://www.davidsmymythe.org/frackland/?p=398) (<https://web.archive.org/web/20230321203127/http://www.davidsmymythe.org/frackland/?p=398>) of the drilling results of Horse Hill-1.



(<https://web.archive.org/web/20230321203127/http://www.davidsmymythe.org/frackland/wp-content/uploads/2018/08/hicks-bayesian-epicentres-with-seismic-refln-data-profiles-AA-BB.jpg>)

Map of available 2D seismic reflection lines in the Newdigate area superimposed on Hicks's earthquake location map. The orange highlighted line runs parallel to Hicks's profile BB' (click to enlarge).

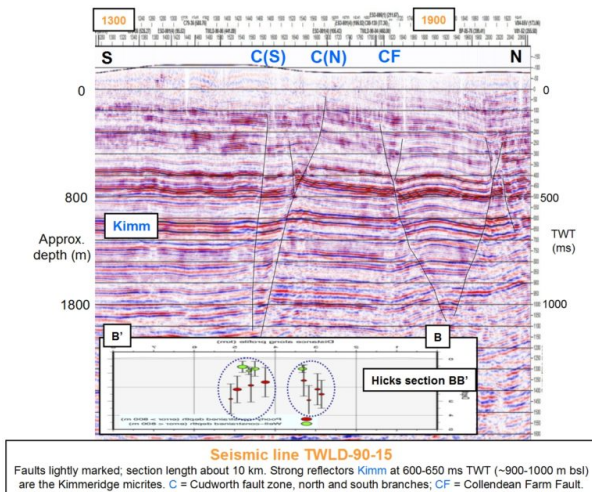
Seismic line TWLD-90-15, highlighted in orange, runs parallel to Hicks's profile BB' shown above. This line shows a fault zone, the Cudworth Fault, which bifurcates upwards into two separate

northerly and southerly strands near the surface marked as C(N) and C(S) respectively. There is also a fault seen on TWLD-90-13, a NNW-SSE trending line through Newdigate, which I have termed the Newdigate Fault, marked with an N on the map.

Note that the Cudworth Fault zone cannot correspond to Sanderson's Russ Hill Fault, because the former is 1 to 2.5 km north of Russ Hill, and, furthermore, does not reach the surface.

It is tempting to correlate the Newdigate Fault with the north Cudworth C(N) strand some 1800 m to the ENE, although I have not done so on the map above. They cannot correlate with the Horse Hill Fault, because (a) the sense of throw is in the opposite sense, and (b) it is known that the Horse Hill Fault dies out 400 to 500 m west of Horse Hill-1. The other seismic lines in the area show an absence of faults in the shallow (0 to 1000 m) subsurface. So the Cudworth and Newdigate Faults must be of limited lateral extent, like the Collendean Farm and Horse Hill Faults.

The section below shows part of line TWLD-90-15. South is on the left, so Hick's section BB' has been mirrored and scaled horizontally for overlay, to match the seismic data as far as possible. Within the limits of error in locating the earthquake hypocentres, there is a good spatial match between the two groups of earthquakes and two shallow Cudworth fault zones, north and south, labelled C(N) and C(S), respectively.



(<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/wp-content/uploads/2018/08/TWLD-90-15-squash-faulting-bayes-hicks.jpg>)

Seismic line TWLD-90-15 with interpreted faults. Vertical scale is in two-way reflection time (TWT); an approximate depth scale is shown at the left-hand side. Hick's profile BB' is positioned below (click to enlarge).

The seismic section shows that the vertical throws on all the faults depicted are small, 50 ms or less (60-80 m). This matches the fact that their lateral extent is limited. The Colleandean Farm Fault is 7 km long; the Horse Hill Fault is 3 km long, and the Cudworth-Newdigate

strands are 4 km long or less, constrained by the surrounding seismic data. However their structure in vertical section, like a negative flower structure, suggests that there may be a component of strike-slip (sieways) displacement. But we don't as yet know the sense of this component of displacement.

Link between the earthquakes and hydrocarbon activity?

Neither of the two employees of Angus Energy quoted above seem to understand basic principles of hydrogeology. Mr Hollis's statement implies that any fluid connection away from the boreholes would only be along fault lines, which, he correctly states, run generally east-west. But he forgets about the permeable horizons in the Jurassic and Cretaceous, and in particular the Brockham reservoir rock, the Portland Sandstone. If the E-W faults are transmissive (a reasonable assumption, and one he makes himself) then injected fluid from Brockham BRX-3 could, in principle, flow south (or north) along the [low- corrected 2018 Aug 16] high-permeability reservoir, crossing through any faults on the way, and aided by confining clays (layers of low permeability) above and below. He cannot argue that re-injecting produced water is simply putting it back where it came from (minus the oil, of course), because produced water from Lydsey has for many years been shipped to Brockham for disposal there.

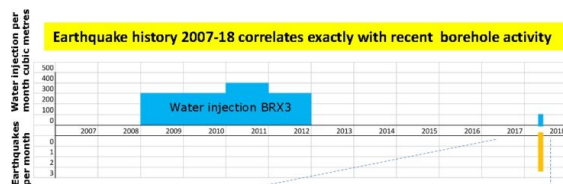
It might also be argued that the distances from Brockham and Horse Hill are too great for there to be a physical connection between injection and the triggering of earthquakes at Newdigate. However, a recent report (<https://web.archive.org/web/20230321203127/https://eos.org/features/fluid-injection-wells-can-have-a-wide-seismic-reach>) published in April in *Eos*, the weekly magazine of the American Geophysical Union, under the self-explanatory headline '*Fluid injection wells can have a wide seismic reach*', shows that fluid pressure from injection and resulting induced earthquakes can be observed more than 20 km away from the injection well. However, the volumes of injection involved, in southern Kansas, are many orders of magnitude greater than at Brockham. I only mention this article to demonstrate that a fluid connection is physically possible; I am not saying that it is probable that there is a similar link between Brockham injection and Newdigate earthquakes. We simply do not have enough information yet.

The several US studies of induced seismicity resulting from produced water injection all concern wells injecting fluid just above 'basement', i.e. at the base of the sedimentary pile at several kilometres down. The novel aspect of the Newdigate earthquakes is their unusual shallowness - less than 1 km depth. They may even be occurring at around the transition depth of a few hundred metres where the maximum compressive

stress in the rocks is horizontal, and not vertical. This change in orientation occurs simply due to the weight of overlying rock becoming the dominant force the deeper you are. On the other hand, the normal fault sense of displacement of Hicks's fault plane solutions does imply that the maximum principal compressive stress is indeed vertical, with the minimum stress component being N-S.

The effect of fluid injection into permeable rock around a fault which has the potential to slip, thereby increasing the pore pressure, is to 'take the weight off' all the stress components, somewhat akin to letting the rocks 'float' to a slight degree. So if the fault zone is critically stressed, that is, it is on the point of failure, the increased pore pressure can alter the relationship between the stress components (including shear stresses) in such a way that the fault moves to release the stress, giving us an earthquake. But until we understand more about the local stress field, and have located more precisely where the fault or faults slipped each time there was a quake, we can only make this qualitative assessment.

The time chart below, by Stuart Haszeldine and Stuart Gilfillan, shows the temporal relationship between Brockham injection, Horse Hill activity, and the earthquakes.



(<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/wp-content/uploads/2018/08/haszeldine-time-chart-brockham.jpg>)

Earthquakes coincide exactly with timing of resumed water injection

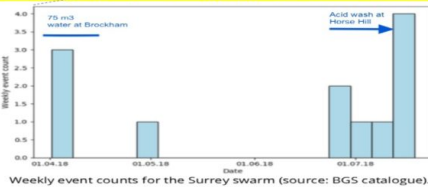
The data below has been provided to the OGD by operators of UK producing fields using the UK Energy Field Production Reporting System and has not been independently verified. No responsibility is taken for the accuracy or completeness of the data. All rights are reserved. No liability is accepted for any errors or omissions. Please email FRPS@ogd.gov.uk if you have any queries.

Field	Date range	Date type	Units	Operator	Labelled or assessed
Water injection (m³)	May 2017 - Apr 2018	Water injection	Volume (m³) (Scale in all gas)	ANUSO ENERGY LIMITED	Other

Reporting date	Operator	May 17	Jun 17	Jul 17	Aug 17	Sep 17	Oct 17	Nov 17	Dec 17	Jan 18	Feb 18	Mar 18	Apr 18	Total
BROCKHAM	ANUSO ENERGY LIMITED	0	0	0	0	0	0	0	0	0	0	1	76	76
HORSE HILL	ANUSO ENERGY LIMITED	0	0	0	0	0	0	0	0	0	0	0	0	0

Time chart of Brockham injection compared with earthquake activity (bottom, from Steve Hicks) (click to enlarge).

Earthquakes coincide exactly with timing of injection at Brockham AND Horse Hill



The diagram does not prove a causal link, but the coincidence is striking. There have been no more earthquakes now for nearly four weeks, since 2018 July 18, so if it can be confirmed that there has been no activity at Horse Hill since the last earthquakes, this would be additional evidence pointing the finger at Horse Hill. On the other hand, earthquakes may continue to be triggered for some time after the cessation of

injection, so absence of further production activity since July 18 plus future earthquakes would not imply that injection or flow testing prior to mid-July was *not* responsible.

In conclusion, the extreme shallowness of the Newdigate events means that we have a lot to learn about shallow pore pressure, shallow stresses, and shallow faults. The complex tectonic problem to be resolved here lies in the depth zone of the hydrocarbon activity. In view of the clear temporal and spatial relationship to the current exploration and production activity at the two sites in question, I support the call for a moratorium on further hydrocarbon activity made by four expert earth scientists.

Surrey quake fears

Sir, A moratorium is urgently needed on hydrocarbon exploration in the area of Surrey recently affected by 12 earthquakes. We believe that public health and the environment are not being adequately protected given the unstable geology, which had not been identified before permits were issued for the currently active drill sites.

The abrupt onset of the earthquake cluster recorded by the British Geological Survey at Newdigate since April 1 requires an explanation and

(https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/wp-content/uploads/2018/08/Times_letter-6aug18.jpg)

Letter to *The Times*, 2018 August 6, from four earth science experts (click to enlarge).

This moratorium must last until such time as independent experts can explain what the link is, if any. The same group of signatories to the *Times* letter has also

gives rise to our concerns about safety. Oil drilling, extraction and re-injection can cause earthquakes.

There are two oil sites in the immediate area: Horse Hill and Brockham. A causal link with either well site cannot be ruled out, so we need the full picture for the risk assessment. Well integrity in these circumstances is a serious concern.

The moratorium on drilling, re-injection and flow testing should be put in place immediately and remain in force until the records of fluid injection and local faulting activity have been comprehensively surveyed and interpreted, and the triggering mechanism for this quake cluster properly understood.

We call on the energy secretary and regulatory bodies to address this issue without delay.

STUART GILLILAN FGS, senior lecturer in geochemistry at School of GeoSciences, University of Edinburgh;
STUART HASZELDINE FRSE, professor of geology, University of Edinburgh;
BELL MCGUIRE, emeritus professor in geophysical and climate hazards, UCL;
RICHARD SELLEY, emeritus professor of petroleum geology, Imperial College London

written in more detail to the Secretary of State at BEIS, calling for a moratorium. Business as usual should not be an option.

Categories: **Angus Energy** (<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/?cat=17>), **Southern England** (<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/?cat=15>), **UKOG** (<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/?cat=16>)



Professor David Smythe (<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/>)

I am Emeritus Professor of Geophysics in the University of Glasgow (a courtesy title). I retired from the University in 1998 and live in France, where I continue my research in geology and geophysics.

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Response to What do we know about the Newdigate, Surrey earthquakes?



Professor David Smythe (<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/>) Post author

13th August 2018 at 12:00 pm (<https://web.archive.org/web/20230321203127/http://www.davidsmythe.org/frackland/?p=498#comment-188>)

Update on earthquake relocation

I have just realised that Steve Hicks has revised his relocations (2018 August 10). The division into two groups is now less clear than I imply above, but his general locations projected onto profile BB' still match well the Cudworth Fault, especially at a slightly deeper depth of 800-1000 m where the two strands come together.

He has also recognised four additional small events not included on my list above from the BGS, and by examining data from the private REC60 seismograph going back in time, he is now more certain than before that the swarm started on 2018 April 1 and not before.