Spatial and temporal change of narrow stress field for the 2016 Kaikoura earthquake

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本研究ではニュージーランドの南島北部で発生した2016年カイコウラ地震の震源域における、応力場の時空間変化を対象とする。定常観測網であるGEONETと臨時観測網の地震波形データを解析に用いている。

今回は新たに2018年のデータを加えてメカニズム解を求め、応力テンソルインバージョンを用いて本震前後の時空間的応力場を求めた。本震断層面上で余震が多く起きている場合、断層面が偏りを持って分布してしまう可能性があるため、本震断層面上で発生した余震メカニズム解の影響を検討する必要がある。そこで、Hamling et al. (2017)の断層モデルとKagan角を用いて、本震断層面上のメカニズム解を取り除くことを試みた。現時点での結果としては、Kagan角の値に依らず、応力場は大きく変わらなかったため、本震断層面上で起きている余震が結果に与える影響は小さいと考えられる。

カイコウラ地震の震源地域を複数の小領域に分けて応力テンソルインバージョンを行った。今回は新たに2018年のデータを加えたが、本震後の結果は前回までの2017年までの地震を用いた結果と同様であり、震源域北東部、中部においては横ずれ断層型の応力場、本震震源を含む南西部では横ずれ断層型と逆断層型の中間的な応力場が推定された。最大水平応力の方向は先行研究と同様に概ねN110Eであり、地震前後での顕著な変化は見られなかった。応力比(phi=(sigma2-sigma3)/(sigma1-sigma3))は、北東部、中部においては本震後に大きくなり、南西部においては小さくなった。

小領域のうち、南西部領域においてイベント数は十分であるにも関わらず、sigma2、sigma3の信頼区間が広く被っていたため、1) 本震後に時間変化が起こっている可能性と2) 応力場が不均質であり、より細かい領域分けが必要である可能性の2通りを考えた。まず、時間変化については、本震後をおおよそ同程度のイベント数になるように3つの期間 (2016.11.13-2016.12.08; 2016/12/09-2017/4/11, 2017/4/12-2018/12/31) に分けて応力場を求めた。南西部において、本震後の3つの期間全てにおいて逆断層型の応力場に近い、逆断層型と横ずれ断層型の中間的な応力場が推定された。また、応力比の値は3つの期間全てで0.17程度を示した。即ちカイコウラ地震後の顕著な時間変化はほぼ生じていないと考えられる。一方、空間変化については、南西部を4つの地域に分割し応力場を求めた。その結果、ほとんどの地域では逆断層型優位の逆断層型と横ずれ断層型の中間的な応力場であったのに対し、最西端の地域のみ横ずれ断層型の応力場となった。

We study spatio-temporal change of the stress field due to the 2016 Kaikoura earthquake in the northern area of the South Island of New Zealand. Data from both 51 temporary stations and 22 permanent GeoNet stations were used. In addition to these data, we determined new focal mechanisms by adding the data of 2018, and estimated the stress field before and after the Kaikoura main shock using stress tensor inversion. If there are many aftershocks on the fault plane of the main shock, the fault plane may be distributed with a bias. Therefore, it is necessary to study the effect of focal mechanisms of aftershock that occurred off the fault plane of the main shock. So, we attempted to remove the mechanism solution on the fault plane of the main shock using the fault model of Hamling et al. (2017) and the Kagan angle. We found that the stress field did not change significantly independent of the value of the Kagan angle, and we consider that the effect of the aftershocks occurring on the fault plane of the main shock on the result is small.

In addition, we carried out the analysis by dividing the hypocenters into several regions. We added new data for 2018, however the results after the main shock are similar to the previous results. The maximum horizontal stress direction is about N110E both before and after the Kaikoura earthquake. In the northeast and central part of the rupture, the stress field types are strike-slip, and in the southwest part of the rupture, the stress field type is intermediate stress field between strike-slip and reverse fault type. The stress ratio (phi = (sigma2-sigma3)/(sigma1-sigma3)) increased after the main shock in the northeastern and central regions, and decreased in the southwestern region. These changes could be interpreted as fluid pressure change (e.g., Warren-Smith et al., 2019) and/or stress heterogeneity changes (e.g., Michael et al., 1990).

Although the number of events was sufficient in the southwestern part, the confidence intervals of sigma2 and sigma3 were wide, so we considered the following two possibilities: 1) the stress field has temporal change after the main shock, 2) It is necessary to divide the area into smaller areas. First, in order to see the temporal change, we calculated the stress fields in three time windows after the main shock (2016/11/13-2016/12/08, 2016/12/09-2017/4/11, 2017/4/12-2018/12/31) so that the number of events in these three time windows would be approximately the same. In the southwestern region, in all three windows after the main shock, a stress field intermediate between the reverse fault type and the strike-slip fault type, which is close to the reverse fault type stress field, was determined. The value of stress ratio was about 0.17 in all three windows. This means no significant temporal change after the Kaikoura earthquake through 2018. The stress field was obtained by dividing the southwestern region into four regions in order to consider spatial change. Except in the westernmost area where the stress field is strike-slip fault type, the stress field was still intermediate between reverse and strike-slip fault type. This is consistent with the co-existence of strike and reverse faults in the North Canterbury Domain (e.g., Ghisetti and Sibson, 2012).