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Quaternary surface ruptures of the inherited mature Yangsan Fault: implications for intraplate earthquakes in Southeastern Korea

| **Comment** | **Change made** |
|---|---|
| ***Reviewer 1*** | |
| ***Major comments*** | |
| This manuscript addresses the paleoseismic and structural features of the Byeokgye section of the Yangsan Fault, SE Korea mainly obtained from the trench surveys. The Korean peninsula is a representative slow-deforming region, but recently, high-resolution seismological and paleoseismological researches have been actively conducted. In particular, the Yangsan Fault holds significant research value for its long-term geological evolution and as a seismogenic fault during the current stress field (Quaternary period). | Thank you for your time and effort to send us constructive feedback. We did our best to reflect the most reasonable opinion. We are sure that the current manuscript has been greatly improved to consider publication. |
| I read whole manuscript thoroughly. The quality of the data presented throughout the manuscript is quite excellent. The academic logic and structure of the paper are also reasonably sound. Despite these strengths, the manuscript needs significant polishing in terms of English expression throughout, and there are many parts that are unnecessarily repetitive and overly lengthy. Consistent and systematic descriptions are also needed across the each result section. I would propose major and minor comments for each individual section of the manuscript. The detailed comments annotated in the PDF file should be also considered. Since I am not a native English speaker, I did not leave extensive comments on the English expressions. I would suggest the authors to ask for help to a native English-speaker or to someone with a better level of English. | Thank you for the kind words.<br>We've done our best to take your feedback on board. First, we've reviewed the English language of the manuscript in general and simplified repetitive content. Additionally, we have tried to keep the text organized. All your major and minor comments have been answered and corrected in detail. To polish the overall English, we took the help of Dr. Chinmay Dash (Indian Geomorphologist; chinmay.ism@gmail.com). We hope that our revised manuscript will please you. |
| Major comments on "3.4. Displacement and earthquake magnitude estimation"<br>I know that there are recent studies on the slip rates of this area published in the GSA Bulletin and Geomorphology. Please present their methodologies and also describe the validity of your method for revealing displacement of a fault.<br>Using this methodology to determine horizontal displacement (or total displacement) has several weaknesses. Describe these weaknesses and clearly describe why, despite them, the | We have changed total displacement to horizontal displacement to reflect your comments. We also noted the limitations and uncertainties of the displacements derived from this study, described in chapter 3.4.<br><br>***Line 224-239***<br>**3.4 Displacement and earthquake magnitude estimation**<br>The slickenlines of the main surface rupture and the vertical separation of the Quaternary sediments in the trench wall are used to determine the horizontal displacement of the MRE and the displacement per event. In general, for strike-slip faults like the study area, horizontal displacements must be obtained from 3D trenches or from topography that preserves the displacements almost intact (e.g., Kim et al., 2024; Naik et al., 2024). Using only 2D trenches to obtain displacements or slip rates is uncertain because the sedimentary layers are unlikely to have recorded all earthquakes. Furthermore, deriving the horizontal displacement is challenging when exposed walls are inclined, markers are inclined, or the slip sense is not purely dip-slip or strike-slip (which is almost always the case). In addition, |

methodology is still meaningful.

displacements based on fragmentary information, such as bedrock separation and thickness of Quaternary sediments, can be over- or underestimated by fault slip motion and the possibility of paleo-topographic relief cannot be ignored. Despite these uncertainties, fault displacement is a necessary factor in earthquake magnitude estimation and key paleoseismological information, and the displacement obtained from the 2D trench can be used as a minimum value; therefore, the process of collecting or estimating fault displacement is indispensable in paleoseismology. Therefore, correlations based on vertical separation, marker dip angle, angle of slope wall, fault dip angle, rake of slickenline, etc. are important for estimating the horizontal displacement of a fault (Fig. B1; Xu et al., 2009; Jin et al., 2013; Lee et al., 2017; Gwon et al., 2021). The method of using their relationship to find the horizontal displacement is described in detail in Appendix B.

***Line 658-671***

**Appendix B. Calculation of horizontal displacement**

The horizontal displacement ($S_h$) can be calculated using a trigonometric function that considers the vertical displacement ($S_v$), fault dip angle (α), rake (γ), true displacement ($S_t$) and their relationships (Fig. B1; Eq. B1). Assume that the attitude of the marker in the exposed wall at each trench is nearly horizontal in three dimensions and the angle (β) of the exposed wall is nearly vertical, then the two factors are perfectly horizontal and vertical, respectively. Thus, the vertical separation ($S_{vm}$) and vertical displacement ($S_v$) measured in the exposed wall are equal.

Therefore,

$$\boldsymbol{S_{vm} = S_v, S_m = \frac{S_v}{\sin\alpha}, S_t = \frac{S_m}{\sin\gamma}, S_h = \cos\gamma * S_t} \quad \text{(B1)}$$

We calculate horizontal displacement ($S_h$) using Eq. (B1) for vertical separation ($S_{vm}$) of the marker measured in the exposed wall, as shown in Table 5.

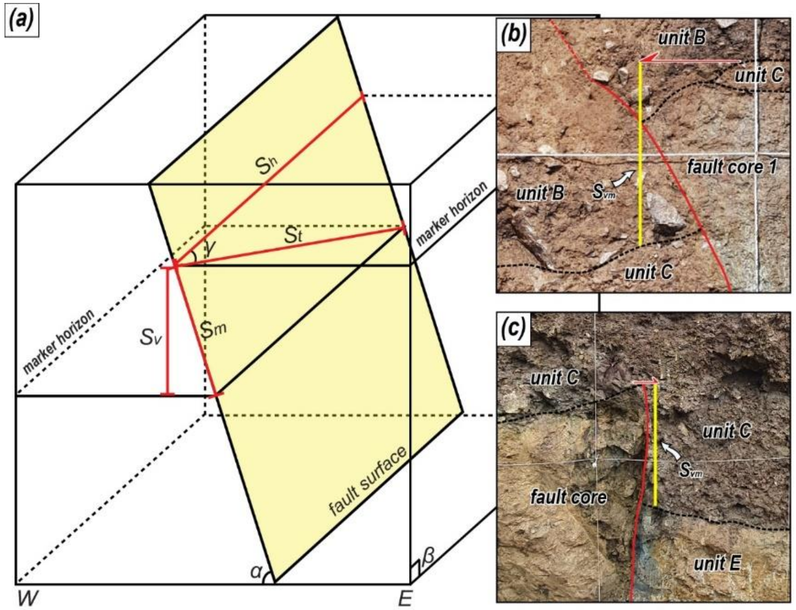


Figure B1: (a) Schematic diagram showing how to calculate true displacement. $S_h$: horizontal displacement $S_t$: true displacement, $S_v$: vertical displacement, $S_m$: dip separation, α: dip of fault surface, β: dip of cut slope, γ: rake of the striation (modified from Xu et al., 2009). (b and c) Photographs showing the measured vertical separation of the trenches 1 and 5. $S_{vm}$: vertical separation.

<table>
<tr>
<td>Major comments on "4.1. Characteristics of Quaternary faulting in the trenches"<br>1) The descriptions of faults for each trench need to be rewritten in a more concise and systematic manner. The descriptions are unfriendly.</td>
<td rowspan="3">We rewrote the description of each trench to be concise and in a consistent order as follows.<br>1, location information, 2. trench neighborhood topography, 3. brief exposed wall, 4. features of the pre-existing fault core, 5. Quaternary sediment or structural features, 6. geometric relationship of rupture to sediments, 7. estimation of the number of faulting events, and 8. age dating results (OSL, IRSL, radiocarbon dating results -> interpretation->ESR age->interpretation of ESR age). Also, we have reduced the amount of information on bedrock fault cores and focused more on Quaternary surface rupture.<br><br>Line 252-300<br>4.1 Characteristics of Quaternary faulting in the trench<br>4.1.1 Trench 1<br>Trench 1, previously reported by Song et al. (2020) and Ha et al. (2022), is summarized as follows:<br>It is located on the main lineament, approximately 1 km north of the Byeokgye site (Fig. 2c), within a cultivated field where a narrow 50 m wide N-S trending valley and a 20 m wide NE-trending valley meet, through which the main lineament passes. To the east of Trench 1, a NE-trending ridge develops, although this is currently difficult to identify due to human modification, while to the west, a hill with a N-S trending ridge is formed (Fig. A2). Fault scarps are distinctly visible along the main lineament, both to the south and north of Trench 1, with small fluvial and colluvial deposits observed on the surface. Nine Quaternary sedimentary units and seven east-dipping splay slip surfaces (F1–F7) cutting the units are found in the E-W trending trench wall (Fig. 3). The hanging wall of F6 is the western boundary of pre-existing fault core more than 2.5 m wide and the footwall of F6 is a 4 m thick Quaternary sedimentary unit overlying the A-type alkali granite. The pre-existing fault core is divided into two zones based on whether it is related to rupturing. Between F6 and F7, the fault core had a 40 cm wide blue fault gouge cutting Quaternary sediments and a weakly developed shear band within the fault gouge. The fault core, eastern side of F7, did not cut the Quaternary sediments and consisted of a brown to dark grey brecciated zone and a gouge zone more than 2 m wide. The stratigraphic features of the nine units are listed in Table 1, and there are two noteworthy observations: First, the triangular-shaped unit D, characterized by a light brown sandy matrix with better sorting and roundness compared to the surrounding units, is surrounded by the slip surfaces (Fig. 3). It indicates that unit D may have been captured by the horizontal displacement of nearby sediments during the faulting event. Second, various types of seismogenic soft-sediment deformation structures (SSDs) are developed in units E and G (Fig. 3, Fig. 10 in Ha et al., 2022). The orientations of slip surfaces ranged from N60°W to N28°E, changing from NW-to NE-striking to the east. The F6 fault splay (N01°E/69°SE) cut through unit B and the F7 splay (N28°E/86°SE) is terminated in unit C. F3, F4 and F5 cut through units D, E, and F, respectively, and are terminated under unit C. F1 and F2 cut through units G, H, and I but not through unit F. The rakes of the slickenline observed on F6 measured 15–55°, indicating a dextral slip with a reverse component. Three faulting events are interpreted based on the geometry of the sediments and the kinematics of the slip surface: (1) The first faulting event involves the rupture of all F1-F7 after the deposition of units G, H, and I before the deposition of unit F, marking the event 1 horizon. (2) The second faulting event occurred after the deposition of units E and F prior to the deposition of unit C, defining the event 2 horizon, with ruptures affecting faults F3 through F7. During this event, dextral slip along faults F5 and F6 displaced unit D. (3) The third faulting event took place after the deposition of units B and C, with rupture limited to faults F6 and F7.<br>OSL/pIRIR$_{225}$ ages are presented in Table 1. We also conducted $^{14}$C and ESR dating on the trench. Three charcoal samples (1803BYG-01-C, 1803BYG-02-C, and 1803BYG-03-C) are collected from unit E and one charcoal sample (1803BYG-04-C) is collected from unit I for radiocarbon dating. The results of samples 1803BYG-01-C and 1803BYG-02-C are 38,420–36,897 and 45,670–43,802 Cal yr BP, respectively (Table 2). However, the ages of these two samples are near the upper limit of the radiocarbon dates and are stratigraphically contradictory, with the lower layer being younger than the upper layer. The age of 1803BYG-03-C (7,821–7,675 cal yr BP) from the upper part of unit E is inconsistent with the OSL age (1803BYG-10-O: ~164 ka). It is possible that liquefaction in unit E caused a disturbance in the sediments and that the radiocarbon and OSL dates do not indicate the exact depositional timing. In addition, the radiocarbon age of 43,292–41,955 cal yr BP for the sample from unit I is near the upper limit of the radiocarbon ages and is thus subject to error. In particular, it is younger than K-feldspar pIRIR$_{225}$ (177±7 ka (1803BYG-07-O)) from unit H, making it unlikely that this age is indicative of the depositional age of unit I. The main surface rupture cut unit B and the MRE using the OSL age of unit B is >3.2±0.2 ka (1803BYG-06-O; Table 1, Fig. 3). The geometry and cross-cutting relationship between the Quaternary sediments and the seven surface ruptures indicated that a pre-existing fault core is reactivated during the Quaternary, resulting in at least three faulting events (Fig.3; Fig. 9 in Song et al., 2020): the first (antepenultimate earthquake, AE) occurring at <142±4 ka (1803BYG-12-O), the second (penultimate earthquake, PE) at >17±1 ka (1803BYG-13-O), and the third at the MRE (Table 1, Fig. 3). For ESR dating, 36 fault gouge samples are collected from eastern side of F7, and ESR dating is performed on 10 of them (1810BYG-01 to 10-E) (Fig. 3). The dates of each sample are presented in Table 3. The</td>
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<td>4) At some trench sites, the authors divide the mature core into core 1 and core 2. Is this particularly meaningful? Focus on clearly distinguishing between the old fault core and Quaternary fault splay in your descriptions. And then, describe the relationship between the Quaternary splay and Quaternary layers.</td>
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<tr>
<td>5) Describe in the following order for age results and interpretations: presentation of OSL and C$^{14}$ results, interpretation of event horizons using these results, presentation of ESR results, and interpretation of older events using these results.</td>
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</table>

weighted average ESR ages of the samples from the same fault viscose band are 245±37 ka (1810BYG-02-E, 1810BYG-10-E), 406±35 ka (1810BYG-01-E, 1810BYG-05-E, 1810BYG-06-E), 387±26 ka (1810BYG-04-E), and 335±53 ka (1810BYG-04-E) (Table 3). Samples with dose-saturated ESR signals (1810BYG-03-E, -07-E, and -08-E) are excluded from the weighted average age calculations. Considering the error, the timing of faulting events using ESR ages at these sites can be determined to be 406±35 and 245±37 ka.

***Line 316-341***

**4.2.2 Trench 2**

Trench 2 is located on the main lineament 0.8 km north of Trench 1 (Fig. 2c), within a colluvial area where fault scarp extend continuously along the main lineament to the south and north. Just north of Trench 2, the transition to an alluvial fan is clearly visible where the mountain ridge meets the main lineament. The 25-m wide valley surface contains partially developed colluvial sediments and deposits from small streams and gullies. Two Quaternary deposits are observed in Trench 2, along a low-angle Quaternary slip surface (N02°E/38°SE) intersecting the Quaternary deposits on the exposed wall (Fig. 4). The minimum 6-m-wide fault core of the hanging wall is composed of mature fault rocks. The fault core is divided into yellow and bluish-grey (Fig. 4). Foliation developed within the yellow fault core, which abutted the Quaternary slip surface in the upper part of the wall. The Quaternary slip surface cuts unit B, displaying thrusting of the hanging wall's pre-existing fault core, while unit A overlies both features. Unit A has a loose matrix and relatively low consolidation compared to the underlying unit B and overlies the pre-existing fault core (Table 1). The slickenline on the Quaternary slip surface shows a dextral slip with a minor reverse component. Only one faulting event is recognized, in which the Quaternary slip surface cuts through unit B, and unit A overlies it (Figs 5b and 5d).

The OSL ages of unit A, which covers the rupture, are 3.4±0.4 ka (1810NSR-06) and 3.2±0.3 ka (1810NSR-05) at the southern wall and 19±1 ka (1810NSR-07) at the northern wall (Table 1). The radiocarbon ages of the charcoal in unit A are 291–0 and 304–0 cal yr BP (Table 2), making them much younger than the OSL age from unit A. Radiocarbon dates do not indicate when the charcoal is deposited with the sediment but when the tree died after being rooted in the ground. The OSL results indicate a depositional age of 3.4±0.4 ka for unit A, which is not cut by the rupture, so the MRE of the surface rupture in Trench 2 is interpreted to be before 3.4±0.4 ka. The ESR ages obtained from the fault gouge are higher than the depositional ages of the sediments cut by the rupture (Table 3). The ESR ages suggest that the quartz ESR signal in the fault gouge is not fully initialized during faulting. Nevertheless, the ESR ages roughly cluster into four periods: 790±60 ka (1810NSR-01-E), 407±37 ka (1810NSR-02, 03-E), 350±49 ka (1810NSR-05, 06-E), and 261±48 ka (1810NSR-09-E).

To estimate the thickness of the Quaternary sediments and the cumulative vertical displacement of the Quaternary slip, drilled sediments are sampled from the footwall along the Quaternary slip surface (Fig. D1). The Quaternary sediments extend to a depth of approximately 32.8 m, underlain by a granite wash (1.2 m thick) of Paleogene A-type alkali granite, and a subsequent fault damage zone of the granite exists at its base (Fig. D1). Therefore, the vertical separation caused by the Quaternary rupture in Trench 2 is at least 34 m. However, the vertical separation is a paleo-topographic relief difference that may have been caused by the strike-slip movement of the Quaternary slip. Cosmogenic $^{10}Be$-$^{26}Al$ isochron dating of the granite wash underlying the Quaternary sediments yielded a burial age of 2,871±593 ka, indicating that the thick Quaternary sediments started to be deposited after 2,871±593 ka (Table 4).

***Line 357-381***

**4.2.3 Trench 3**

Trench 3 is located on the main lineament extending 1.7 km north of the Trench 2 (Fig. 2c), within a cultivated field next to a wide road at the mouth of a broad basin. Fault scarps along the main lineament extend both south and north of the Trench 3. This trench marks the northernmost point where the transition to the alluvial fan is observed where the mountain ridge meets the main lineament; beyond this point, fault scarps continue to develop on the alluvial fan surface. Eight Quaternary sedimentary units and three fault splays are identified in the trench wall (Fig. 5, Table 1). The hanging wall of the Quaternary slip zone, which cut through Quaternary sediments, is composed of a pre-existing fault core. Excavation revealed a fault core at least 20 m wide. The fault gouge zone that cut the Quaternary sediments is narrower than 5 cm at the bottom of the wall and widened to 40 cm at the top of the wall; it is divided into a greyish-white gouge zone and a red gouge zone by color and slip surface. The red fault gouge zone is almost entirely composed of clay; however, there are numerous uncrushed quartz and rock fragments within the grayish-white gouge zone. The characteristics of the eight units are shown in Table 1. Unit D is a colluvial wedge that indicates a paleo-earthquake (Fig. 5, Table 1). Brown sand to fine (units F and H) and brown gravel (units C, E, and G) deposits are in the trench wall. These features can be attributed to environmental factors, such as deposition due to repeated rainfall, flooding, or seismic events due to repeated seismic motion. The Quaternary slip zone cuts through unit C, including unit D, a colluvial wedge, and is covered by unit B. The slickenline observed on the fault splays indicates a dextral slip with a small reverse component. There are at least two estimated faulting events in this exposed wall: event 1, which formed a colluvial wedge, and event 2, which cut the colluvial wedge (Fig. 5).

The $pIRIR_{225}$ ages of sample 1903NR1R-02 and 03-O from unit E at the southern wall are 173±6 ka and 175±5 ka, respectively. In contrast, the $pIRIR_{225}$ age of 1903NR1R-08-O from unit D, which is the colluvial wedge that directly indicates the timing of a faulting event, shows that the deposit formed at 137±3 ka (Table 1). Additionally sample 1903NR1R-10-O from unit B, which covers the rupture, is dated as 6.4±0.4 ka. These findings suggest that the first surface rupture occurred at 137±3 ka, as indicated by the colluvial wedge, and the next surface rupture occurred before 6.4±0.4 ka indicated by event 2 horizon. The youngest ESR age for the fault gouge is 409±52 ka (1903NR1R-02-E, Table 3). However, since the quartz ESR signal in the fault zone may not fully reset during faulting, this age implies that the faulting event occurred at or after 409±52 ka. The ESR ages cluster into two time periods: 417±59 ka (1903NR1R-01, 02-E), 702±123 ka (1903NR1R-03-E).

***Line 388-408***

**4.2.4 Trench 4**

Trench 4 is situated on a NE-striking eastern branch lineament from the main lineament, which stretches 2.8 km north of the Trench 3 (Fig. 2c). South of Trench 4, a continuous dextrally deflected stream follows the branching lineament, with smaller displacements identified further north. Trench 4 lies at the edge of an alluvial fan near a hillslope, with two features separated by a stream. Within the trench wall, five Quaternary sedimentary units are cut by a surface rupture (Fig. 6, Table 1). The hanging wall of the Quaternary fault splay includes a pre-existing fault core at least 5 meters wide at the time of excavation. Adjacent to the Quaternary sediments, a 20-cm-wide fault gouge zone developed, characterized by yellowish-brown and reddish-brown gouges. Units A and B exhibit horizontal to sub-horizontal bedding, while the bedding of units C-F tilts westward, with dips of up to 50° near the surface rupture, becoming shallower to the west (Fig. 6, Table 1). The difference in bedding orientations indicates an angular unconformity between unit B and units C–F. A surface rupture, covered by unit A, cuts through all of units C-F, including the unconformity, but does not extend through all of unit B. The slickenlines observed on the fault splay indicating dextral slip with a minor reverse component. At least two faulting events are inferred from the exposed wall: the first faulting event (PE) caused the tilting of units C–F after deposition (event 1 horizon), and MRE occurred during the deposition of unit B, following the formation of the angular unconformity (Fig. 6).

We collected five samples from the northern wall of units A and B. The OSL age of 5.9±0.4 ka was obtained from 2009UGR-09-O, which is cut by the rupture. For the remaining four samples that are not cut by the rupture, the oldest OSL age is 1.3±0.1 ka, recorded for 2009UGR-05-O (Table 1). Additionally, samples were collected from units F (2009UGR-01-C) and A (2009UGR-02-C) for radiocarbon dating (Table 2). The radiocarbon age of the charcoal from 2009UGR-02-C is 160±30 cal yr BP, which aligns with the OSL age of 0.15±0.01 ka for the sediment containing the charcoal (2009UGR-07-O), and strongly indicating that unit A was deposited at this time. Based on the the comprehensive dating analyses, the MRE for this trench occurred between 5.9±0.4–1.3±0.1 ka, as the faulting event took place during the continuous deposition of unit B.

***Line 415-432***

**4.2.5 Trench 5**

Trench 5 is located 40 m north of Trench 4. Because of its proximity, Trench 5 shares identical topographic characteristics with Trench 4, except that it lies on the margins of a hillslope instead of on an alluvial fan. The trench wall contained five quaternary sedimentary units, cut by one fault splay (Fig. 7). The overall appearance of the exposed wall is similar to that of Trench 4. The hanging wall of the fault splay that cut the Quaternary sediments consisted of a pre-existing fault core at least 20 m wide. Where it abuts the Quaternary sediments, a 10 cm wide light grey fault gouge developed, which changed to a yellowish grey fault gouge with yellow clay mixed toward the top. Units A-C show subhorizontal bedding, units D and E show westward-dipping bedding, and there is an angular disconformity between units C and D. Trenches 4 and 5 are almost the same because they are adjacent, with units A-C in Trench 5 matching units A, B in Trench 4 and units D, E in Trench 5 matching units C-F in Trench 4. The reddish-brown sediments in the upper part of Trench 5 appear to be thicker than in Trench 4 because it is the tip of a hillslope. The Quaternary fault splay cut unit C but failed to cut unit B. The slickenline observed on the high-angle Quaternary fault splay indicated a dextral slip with a small reverse component. At least two faulting events are estimated, based on the same angular unconformity as in Trench 4. Event 1 caused units D and E to tilt, which cut them (event 1 horizon, Fig 7). Event 2

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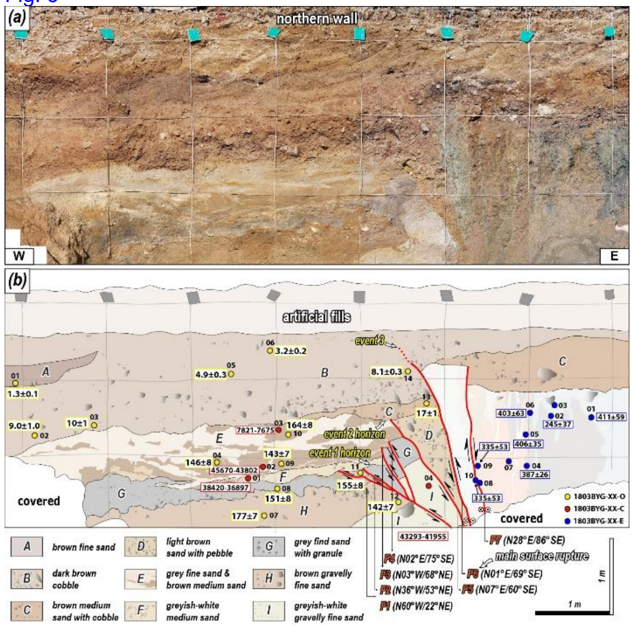
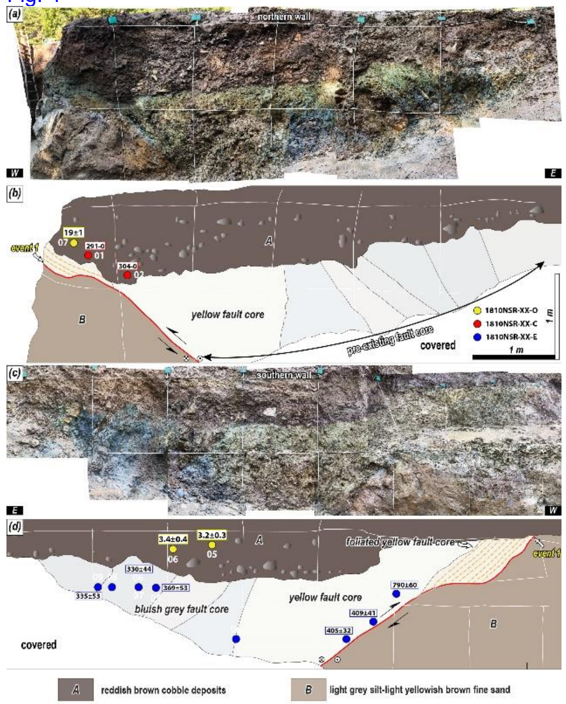
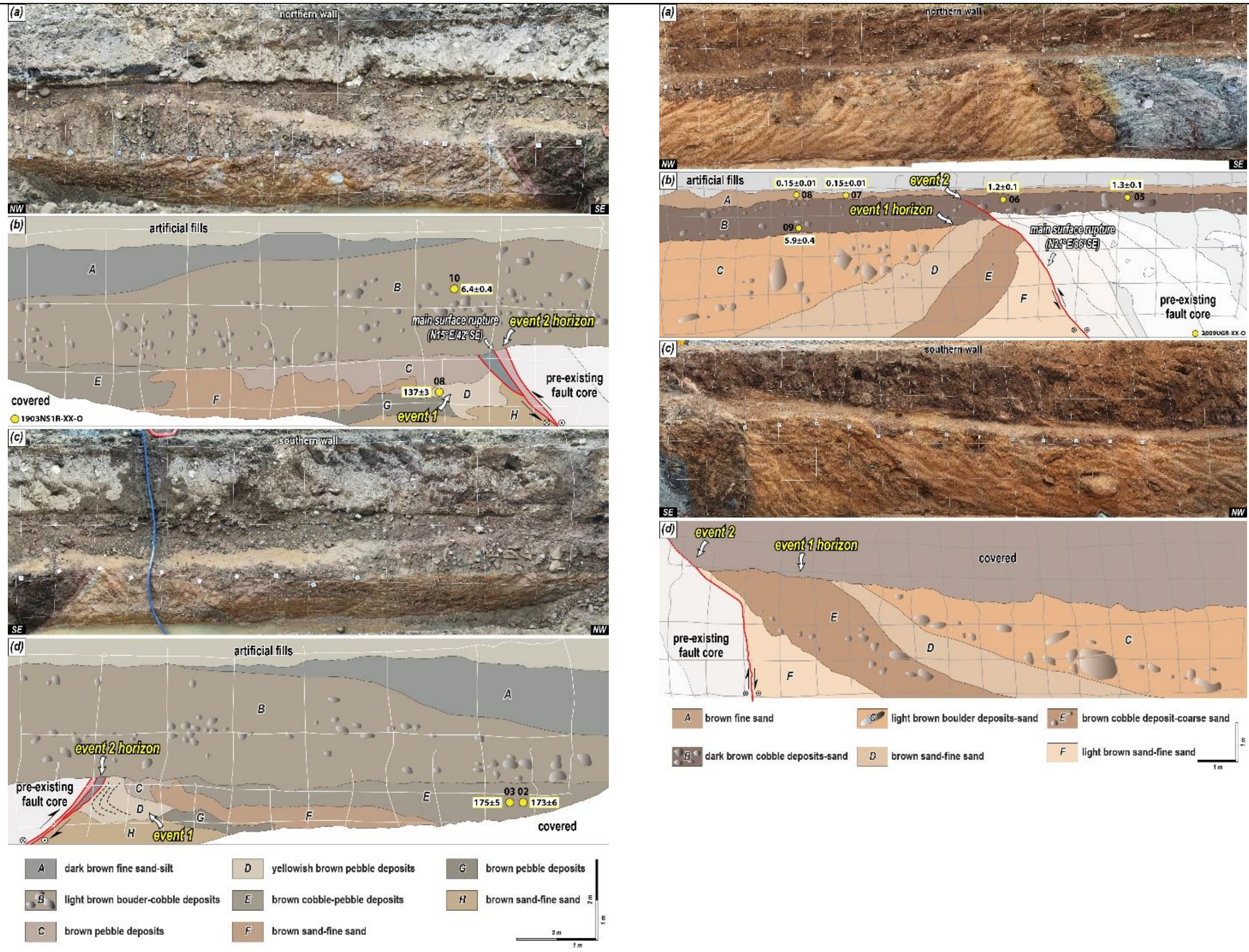
|---|---|
| | occurred during the deposition of unit C, which failed to cut into unit B.<br>The OSL ages on the southern wall of 2010UGR-03-O and 04-O from unit B are 2.8±0.1 and 2.6±0.1 ka, respectively, and those of 2010UGR-01-O and 02-O from unit C are 10±1 and 4.8±0.2 ka, respectively (Table 1). The fault splay is cutting through unit C and failing to cut through unit B. Therefore, trench 5 yielded a tighter MRE range of 4.8±0.2–2.8±0.1ka than the MRE of Trench 4. |
| 2) The past tense is being used where it would be more appropriate to use the present tense. Please check carefully. | We checked carefully throughout the manuscript and changed past sentences to present sentences. |
| 3) Clearly distinguish and describe the fault core, fault damage zone, and fault rocks of the bedrock faults (a few cm to m scales), and the fault splays of the Quaternary faults (<2 cm in thickness). For example, I suggest using the term "fault" for bedrock faults and "splay" or "rupture" or "Quaternary slip zone" for Quaternary faults. This part of the manuscript is quite confusing throughout. | Good point.<br>As suggested, we have used the term “fault” throughout the manuscript for bedrock faults, and “(fault) splay, (surface) rupture, and Quaternary slip surface” for Quaternary faulting. |
| 6) Present the age dating results in a table, and in the main text, concisely and clearly describe only those results necessary for actual interpretation. | We've combined Tables 1 and 2 to make them easier to read at a glance, and we've revised Chapter 4.1 to reflect your comment #4.1. |

**Table 1. Description and OSL/pIRIR$_{255}$ dating results of the units in each trench**

| Unit | Features | Age | | |
|---|---|---|---|---|
| | | Age (ka) | Dating method | Sample number |
| **Trench 1** | | | | |
| A | Brown fine sand, lens shape in unit B, coarsening upward in the bottom (silt to fine sand) | 1.3 ± 0.1 | OSL | 01 |
| B | Dark brown cobble, fine sand matrix, poor roundness, fining upward in clast (cobble to pebble) and matrix (sand to fine sand), the youngest unit cut by rupture | 9.0 ± 1.0 | OSL | 02 |
| | | 10 ± 1 | OSL | 03 |
| | | 4.9 ± 0.3 | OSL | 05 |
| | | 3.2 ± 0.2 | OSL | 06 |
| | | 8.1 ± 0.3 | OSL | 14 |
| C | Brown medium sand with cobble, good roundness and sorting compared to unit b, pinch out in footwall, cover the pre-existing fault core | 17 ± 1 | OSL | 13 |
| D | Light brown sand with pebble, good roundness and sorting despite adjacent rupture, captured by a triangular shape, with ruptures | | - | |
| E | Grey fine sand & brown medium sand, mixing with grey and brown parts, SSDS (load structure dominated; load cats, pillar structure, sand dike, disturbed structure, structureless sediments) | 146 ± 8 | pIRIR$_{225}$ | 04 |
| | | 143 ± 7 | pIRIR$_{225}$ | 09 |
| | | 164 ± 8 | pIRIR$_{225}$ | 10 |
| F | Greyish-white medium sand | | - | |
| G | Grey fine sand with granule, SSDS (intrusive structure dominated; ball and pillow, flame structure, sand dike) | 151 ± 8 | pIRIR$_{225}$ | 08 |
| | | 155 ± 8 | pIRIR$_{225}$ | 11 |
| H | Brown gravelly fine sand, moderate roundness and sorting | 177 ± 7 | pIRIR$_{225}$ | 07 |
| | | 142 ± 7 | pIRIR$_{225}$ | 12 |
| I | Greyish-white gravelly fine sand, matrix derived from granite that basement rock | | - | |
| **Trench 2** | | | | |

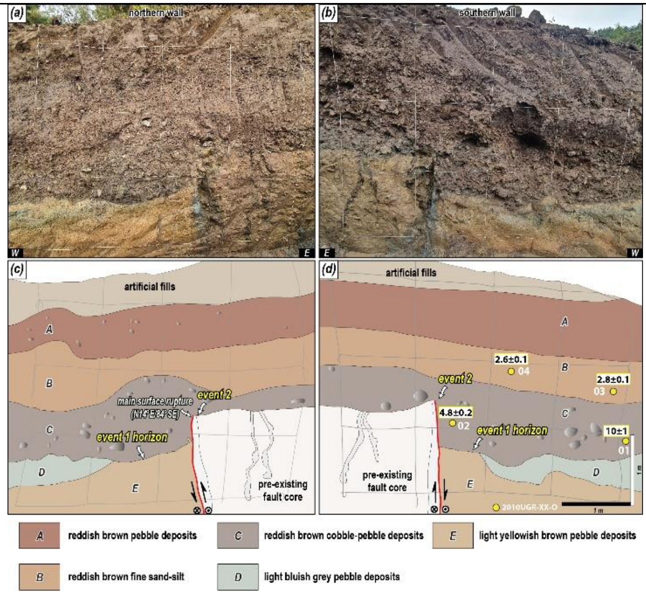
| | | | | |
|---|---|---|---|---|
| A | Reddish brown cobble deposits, A subangular clast composed of granitic and sedimentary rocks with a maximum diameter of 40 cm, poor sorting, charcoal in the bottom, cover the pre-existing fault core | 3.2 ± 0.3 | OSL | 05 |
| | | 3.4 ± 0.4 | OSL | 06 |
| | | 19 ± 1 | OSL | 07 |
| B | Light grey silt-light yellowish brown fine sand, interbedded two layers, cut by surface rupture | | - | |
| **Trench 3** | | | | |
| A | Dark brown fine sand-silt | | - | |
| B | Light brown boulder-cobble deposits, colluvial deposits from mountain slopes, moderate roundness, decreasing the clast size toward the west, cover the Quaternary slip zone | 6.4 ± 0.4 | OSL | 10 |
| C | Brown pebble deposits, poor roundness and sorting, brown sand matrix, the youngest unit cut by fault splays | | - | |
| D | Yellowish-brown pebble deposits, colluvial wedge, triangular shaped, angular to subangular clast, poor sorting in bottom, fining upward, sand content increases with distance from the main Quaternary slip zone | 137 ± 3 | $pIRIR_{225}$ | 08 |
| E | Brown cobble-pebble deposits, subangular clast, poor sorting, intercalated fine sand to silt | 173 ± 6 | $pIRIR_{225}$ | 02 |
| | | 175 ± 5 | $pIRIR_{225}$ | 03 |
| F | Brown sand-fine sand | | - | |
| G | Brown pebble deposits, subangular clast, poor sorting, clast composed of granitic, volcanic, sedimentary rocks | | - | |
| H | Brown sand-fine sand | | - | |
| **Trench 4** | | | | |
| A | Brown fine sand, have a charcoal | 0.15±0.01 | OSL | 07 |
| | | 0.15±0.01 | OSL | 08 |
| B | Dark brown cobble deposits-sand, colluvial deposits from mountain slopes, subangular clast, poor sorting, the youngest unit cut by surface rupture | 1.3 ± 0.1 | OSL | 05 |
| | | 1.2 ± 0.1 | OSL | 06 |
| | | 5.9 ± 0.4 | OSL | 09 |
| C | Light brown boulder deposits-sand, matrix is coarse sand to sand, angular clast, poor sorting, clast mainly composed of granite, the maximum diameter of a clast is ~ 120 cm | | - | |
| D | Brown sand-fine sand, fining upward | | - | |
| E | Brown cobble deposits-coarse sand, alternating sand and gravel, average diameter of clast is 2-5 cm, subangular to angular, moderate sorting | | - | |
| F | Light brown sand-fine sand | | - | |
| **Trench 5** | | | | |
| A | Reddish brown pebble deposits, A subangular clast composed of granitic, sedimentary, volcanic rocks with a maximum diameter of 15 cm, good sorting, matrix-supported | - | | |
| B | Reddish brown fine sand-slit, weak horizontal bedding, the youngest unit cut by surface rupture, no truncation or deformation after MRE. | 2.8 ± 0.1 | OSL | 03 |
| | | 2.6 ± 0.1 | OSL | 04 |
| C | Reddish brown cobble-pebble deposits, fine sand matrix, clast composed of granitic, sedimentary, volcanic rocks, angular to sub-angular clast, poor sorting, containing clasts almost 40%. | 10 ± 1 | OSL | 01 |
| | | 4.8 ± 0.2 | OSL | 02 |
| D | Light bluish-grey pebble deposits, light grey fine sand matrix, the maximum diameter of a clast is ~ 20 cm, clast composed of sedimentary, volcanic rocks, angular to sub-angular clast, poor sorting | - | | |
| E | Light yellowish brown pebble deposits, A slit near the rupture gradually increases in grain size as it moves away, changing to a pebble deposit, angular to sub-angular clast, good sorting | - | | |

<table>
<tr><td></td><td></td></tr>
<tr><td>7) If the sample locations and dating results are included in each figure, it will make it easier for readers to understand.</td><td rowspan="2">We added the sample number and each dating result in the trench logs. We also removed the color of the bedrock part to clearly distinguish it from the Quaternary deposits.<br>Fig. 3 Fig. 4<br><br><br><br><br>Fig. 5 Fig. 6</td></tr>
<tr><td>8) Please make that the colors clearly differentiate between the bedrock parts (including old fault rocks) and the Quaternary layers in each figure.</td></tr>
</table>



(a)
northern wall
NW
SE
(b)
artificial fills
A
B
10
6.4±0.4
main surface rupture (N15°E/42°SE)
event 2 horizon
C
08
137±3
D
E
F
G
H
event 1
pre-existing fault core
covered
1903NS1R-XX-O
(c)
southern wall
SE
NW
(d)
artificial fills
A
B
event 2 horizon
pre-existing fault core
C
D
G
H
event 1
F
E
03 02
175±5
173±6
covered
A dark brown fine sand-silt
B light brown bouder-cobble deposits
C brown pebble deposits
D yellowish brown pebble deposits
E brown cobble-pebble deposits
F brown sand-fine sand
G brown pebble deposits
H brown sand-fine sand
(a)
northern wall
NW
SE
(b)
artificial fills
0.15±0.01
08
0.15±0.01
07
event 2
1.2±0.1
06
1.3±0.1
05
A
event 1 horizon
B
09
5.9±0.4
main surface rupture (N21°E/86°SE)
C
D
E
F
pre-existing fault core
(c)
southern wall
SE
NW
(d)
event 2
event 1 horizon
covered
E
D
C
pre-existing fault core
F
A brown fine sand
B dark brown cobble deposits-sand
C light brown boulder deposits-sand
D brown sand-fine sand
E brown cobble deposit-coarse sand
F light brown sand-fine sand

Fig. 7

| | |
|---|---|
| |  |
| 9) When describe a range of ages, list the older age first. | We reordered all ranges of ages as suggested. |
| Major comments on "4.3. Paleo-stress reconstruction"<br>In the text, Quaternary faults and bedrock faults are described separately, but the figures only present the results for the Quaternary faults. It would be better to state in the text that the focus is on the striations indicating Quaternary faults, without considering the bedrock faults. | We removed the ambiguous sentence and we now focus on the Quaternary fault as you suggested.<br><br>***Line 339-345***<br>"The 20 slickenlines found in the trench are divided into those in the Quaternary slip surface that cut the Quaternary sediments and those in the pre-existing fault core. For the reconstruction of the paleo-stress field, twenty kinematic data along with the geometry of the fault planes and slickenlines were collected and analyzed using Wintensor S/W (v.5.8.5) (Delvaux & Sperner, 2003). Based on the slickenlines of the Quaternary slip surface, the analysis yielded a maximum horizontal stress ($\sigma_{Hmax}$) in the ENE-WNW direction (R´=1.62; Delvaux et al., 1997; Fig. 8), which agrees with the current stress field on the Korean Peninsula (Kim et al., 2016). The reconstructed paleo-stress indicated that the dextral slip with a small reverse component identified in the Quaternary slip surface occurred in an ENE-WSW strike-slip stress regime." |
| Major comments on "4.4. Displacement and earthquake magnitude estimation"<br>Please consider the comments in Section 3. | We've revised chapter 4.4 to reflect both your major and minor comments. We derived the horizontal displacement and used it to infer the maximum earthquake magnitude.<br><br>***Line 450-468***<br>**4.4 Displacement and earthquake magnitude estimation**<br>The results calculated using the marker, vertical separation of each trench, and Eq. (B1) are listed in Table 5. In the previous study by Lee et al. (2016), the horizontal displacement of the MRE at the Dangu site is determined to be 2.55 m. For each surface rupturing event in Trench 1, the horizontal displacement per event according to the event horizon is 0.9–1.05 m, and the horizontal displacement of the MRE is 1.72 m. Using the bedrock and Quaternary sediments unconformity identified by corings in Trench 2 as a marker, the cumulative horizontal displacement is 76 m. The MRE cutting the colluvial wedge in Trench 3 has a horizontal displacement of 2.85 m. However, when considering the overall interpretation, only the MRE and AE, but not the PE, are recognized in Trench 3 (Figs. 5 and 9). The displacement cutting the colluvial wedge likely reflects the displacement of the missing PE as well as the MRE, which is supported by the long interval |

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| | between the wedge (unit D) and the deposit covering the wedge (unit B). Thus, it is reasonable to exclude the calculated displacement as it is unlikely to be the displacement of the MRE. The horizontal displacement of the MRE in Trench 4 and 5 are 0.82 m and 2.21 m, respectively, using the lower boundary of units B and C as markers. Combining the results from each trench, the horizontal displacement of MRE in the study area is 0.82–2.55 m and the cumulative horizontal displacement is 76 m. The horizontal displacement per event is similar, between 0.9–1.05 m for PE and AE (event 1, 2), but the trench shows a higher displacement for the MRE (event 3).<br>We estimated the maximum earthquake magnitude by applying the MD (horizontal displacement: 0.82-2.55 m) of the MRE, resulting in a maximum magnitude estimate 6.7–7.1. Seismic SSDs such as the 20-50 clastic dike and 30 cm ball-and-pillow structure observed in the exposed wall (units E and G in Trench 1; unit F in Trench 3), serve as indirect evidence indicating an earthquake of at least magnitude 5.5 (Atkinson et al., 1984). |
| Major comments on "5.1.2. Quaternary slip rate and recurrence interval"<br>In this section, describe the slip rate compactly for each trench section that can present long-term data, and then for the entire section as well. As long as I know, the slip rate is generally not discussed using MRE. It is reasonable to discuss the slip rate only when there are two or more events with displacements. For example, if an earthquake with the surface displacement occurred 10 years ago, it is not possible to calculate the slip rate using the displacement associated with the earthquake and the 10-year time period. The slip rate is generally considered a long-term concept. | In response to your constructive comments, we have removed all slip rates based solely on MREs, and have noted the slip rates with clear time gaps and detailed how they are calculated.<br><br>***Line 493-518***<br>"The slip rate is an expression of the average displacement of a fault over a certain period, which numerically shows how quickly energy (stress) accumulates in a fault zone and is used as an important input parameter in seismic hazard assessment (Liu et al., 2021). The horizontal slip rate in the study area is calculated based on the earthquake timing and horizontal displacement of each trench. We calculated slip rates from three trenches spanning different periods: Late Pleistocene to Holocene (Trench 1), Quaternary (Trench 2), and Middle Pleistocene to Holocene (Trench 3). In Trench 1, we derived a slip rate of 0.12-0.14 mm/yr based on the horizontal displacement of event 3 (MRE) of 1.72 m and the 13.8±1.2 ka time interval between events 3 and 2 (time gap between units B and C; Table 1). For Trench 2, borehole data revealed a slip rate of 0.02-0.03 mm/yr, calculated from the cumulative horizontal displacement of 76 m and the cosmogenic $^{10}Be$-$^{26}Al$ isochron burial age of 2.87±0.59 Ma from the lowermost Quaternary deposits. In Trench 3, we calculated a slip rate of 0.02 mm/yr using the 2.85 m horizontal displacement of the event that cut the colluvial wedge (unit D) and the 130.6±3.4 ka time interval between events (time gap between units B and D).<br>Considering the age of the deposits, the slip rate of 0.12-0.14 mm/yr from Trench 1 represents movement during the Holocene, while the rates from Trenches 2 and 3 may represent cumulative slip rate (0.02 mm/yr) throughout the Quaternary. As noted in the method section (3.3), there are uncertainties in obtaining slip rates from 2D trenches alone on strike-slip faults such as the study area. In particular, the discontinuous distribution of Quaternary sediments may have led to a misestimation of the slip rate. There are two distinct types of sediments in the trench wall: (1) light brown, relatively coarse-grained sediments of mid-to-late Pleistocene age, which tend to be tilted in the vicinity of the surface rupture, and (2) dark brown, relatively coarse-grained, nearly horizontal Holocene sediments (Table 1, Figs. 3-7). The exact absolute time interval between these two deposits is unknown; however, there is unconformity, and the MRE mostly cut Holocene sediments (<10,000 years). A depositional gap, such as an unconformity, causes earthquake records to be missed during that time, leading to a misestimation of the slip rate. For this reason, in strike-slip fault settings, 3D trenching should be used because the slip rate using displacement from 2D trenches is underestimated compared to the slip rate using topography, which preserves most of the displacement. The slip rates in this study (0.12-0.14 mm/yr) are lower compared to the slip rates derived from the topography and 3D-trench reported in the study area of 0.38-0.57, 0.5 mm/yr, respectively (Kim et al., 2024; Naik et al., 2024). Nevertheless, the slip rates in our study are meaningful as a minimum value that establishes a lower boundary for the slip rates in the study area." |
| Major comments on "5.2. Structural patterns of Quaternary reactivation of the Yangsan Fault"<br>In this discussion section, please focus on how the western boundary of the preexisting mature fault core has been repeatedly reactivated during the Quaternary. I propose that first, describe the characteristics of the bedrock faults, and the features of the Quaternary faults at the western boundary, and then explain why ruptures are repeated propagated along the western boundary of the mature fault core. | We focused on Quaternary surface rupture over bedrock descriptions. We simply combine the evidence presented in the manuscript with evidence from previous papers to state that the rupture occurred at the western boundary of the fault core.<br><br>***Line 533-549***<br>"**5.2 Structural patterns of Quaternary reactivation of the Yangsan Fault**<br>The trenches revealed the following common features. First, the hanging wall of the Quaternary slip surface is mostly deposited with Holocene sediments only, with no Middle Pleistocene sediments present. This indicates that reverse faulting has occurred continuously since at least the Middle Pleistocene. Second, NNE to N-S striking Quaternary slip surfaces with high-angle dip have rakes of 20° or less, indicating dextral slip with a minor reverse component. Third, the main surface rupture has a top-to-the-west geometry, and its hanging wall consists of a pre-existing fault core in all trenches. Fieldwork and previous studies revealed that the A-type alkaline granite in the study area is a dextral offset marker of the Yangsan Fault (Hwang et al., 2004, 2007a, b), and vertically drilled borehole from the footwall of Trench 2 revealed that the basement rock is A-type alkali granite. In addition, Kim et al. (2022) conducted inclined borehole drilling and |

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| | microstructural studies in the vicinity of Trench 1 and identified a fault damage zone, undeformed wall rock, and a fault core approximately 25 m wide on the eastern side of the A-type alkali granite. Multiple lines of evidence demonstrate that the pre-existing fault core distributed on the trenches is the main fault core zone of the Yangsan Fault cutting the A-type alkali granite and that the western boundary of the main fault core is reactivated during the Quaternary. The slip surface where the A-type alkali granite contacts the main fault core suggests that it is in a more slip-prone state (e.g., low coefficient of friction, foliated smectite-rich slip zone; Woo et al., 2015; Kim et al., 2022) during the Quaternary than other slip surfaces within the fault core. Taken together, these results demonstrate that the western boundary of the fault core within the Yangsan Fault zone has been reactivated as a dextral slip with a small reverse component since at least the Early Pleistocene, causing surface rupture in the study area.” |
| Major comments on “5.3. MRE and activity for each segment of the Yangsan Fault”<br>This discussion addresses the MRE of the several active segments of the Yangsan Fault, specifically focusing on the Byeokgye-Bangok-Yugye segment. I suggest that the authors present your research findings first (Byeokgye-Bangok-Yugye), then follow with the results from the other sections. When describing, please enhance readability by making clear comparisons. | We modified the sentences.<br><br>***Line 570-587***<br>“The MRE of the Yangsan Fault is analyzed section-by-section by synthesizing previous studies (Fig. 10). The Bangok (BG) and Yugye (YG) sites adjacent to the north of the study area have similar MREs. The Bangok site, which is closest to the study area, shares the same MRE, after 3,000 years ago (Lee, 2023), while the Yugye site has the youngest MRE along the entire Yangsan Fault, after AD 646 (Kyung, 2003). It is clear that the section from the study area to the Yugye site, including the Bangok site, is the most recently ruptured section of the Yangsan Fault, with the last surface rupture occurring approximately 3,000 years ago (red arrow in Fig. 10). The Bogyeongsa (BGS) site, north of the Yugye site, has an MRE of Middle Pleistocene and Holocene (Lee et al., 2022). The Yeongdeok area, which extends from the northern part of the Bogyeongsa site to Goesi (GOS) site, has several reported Quaternary fault sites though no conclusive evidence of Quaternary faulting exists. This is due to either the cutting of unconsolidated sediments without age constraint or the lack of displacement of unconsolidated sediments, with only ESR ages available for the fault gouge (Choi et al., 2012). The MREs at the Ogok (OG), Pyeonghae (PH), and Goesi sites in the northernmost region of the northern Yangsan Fault date to both Late Pleistocene and Holocene (Choi et al., 2012; Han et al., 2021; Ko et al., 2022). Overall, the northern part of the Bogyeongsa site (the northern part of the Northern Yangsan Fault) experienced MREs between the Late Pleistocene and the Holocene. The Angang area beyond the south of the study area has no reports of Quaternary faulting and at the Wolsan (WS) site, in the northernmost part of the southern Yangsan Fault, the MRE is Late Pleistocene. The Miho (MH), Inbonorth (IBN), and Inbo (IB) sites of the southern Yangsan Fault are all Late Pleistocene and the southernmost part of the Yangsan Fault, the Gasan (GS) site, is after the Late Pleistocene (Lim et al., 2021). The Southern Yangsan Fault from the Wolsan site to the Gasan site experienced MREs mostly in the Late Pliocene.” |
| ***<u>Minor comments</u>*** | |
| Title<br>The entire sentences should be polished by English native or someone with a better level of English. The expression in the sentences also need to be generally clarified. In addition, in terms of overall tense usage, the past tense is being used where it would be more appropriate to use the present tense. | To polish the overall English, we took the help of Dr. Chinmay Dash (Indian Geomorphologist; chinmay.ism@gmail.com), and we checked the manuscript carefully and changed past sentences to present sentences. |
| 12: South Korea<br>- the Korean Peninsula | We modified the sentence.<br>***Line 12***<br>“such as the Korean Peninsula” |
| 13: zones<br>- distributions<br>; Fault zone is fault core and fault damage zone. The internal structure of a fault zone located in the interplate region can be more complex than a fault zone in intraplate. Use precise terminology to accurately convey the meaning! | We modified the sentence.<br>***Line 13***<br>“of fault distribution” |

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| 13: detect<br>- reveal | We modified the sentence.<br>***Line 13***<br>“sources to investigate” |
| 14: to improve seismic hazard assessment<br>- This paper focuses on paleoseismologic and structural parameters that can be utilized for SHA, rather than directly addressing SHZ itself. It would be modified such below.<br>: to understand its long-term earthquake behavior | We modified as suggested.<br>***Line 14***<br>“Yangsan Fault, aiming to understand its long-term earthquake behavior” |
| 14: Paleoseismic data<br>- Paleoseismic data of the Byeokgye section (?? km) of the Yangsan Fault | We modified the sentence.<br>***Line 14-16***<br>“Paleoseismic data of the Byeogye section (7.6 km) of the Yangsan Fault are analyzed to provide insights into earthquake parameters (i.e., timing, displacement, and recurrence intervals) as well as structural patterns.” |
| 14-15: seismic activity, displacement, and structural patterns.<br>- earthquake parameters (i.e., timing, displacement, and recurrence interval) and structural pattern | |
| 15: at least three faulting events<br>The "at least three faulting events" mentioned in here do not take into account ESR age results. The authors need to consider the your age results of both OSL and ESR but also related age periods. OSL age data are just <10 ka. | We modified the sentences.<br>***Line 16***<br>“sites indicate at least six faulting events” |
| 16-18: These events resulted in a cumulative displacement of 3.1–94.0 m and maximum estimated magnitude of 6.7–7.2. The average slip rate of 0.14 mm/yr suggests a quasi-periodic model with possible recurrence intervals exceeding 10,000 years.<br>- It is somewhat illogical. Please find the main comment. | We modified the sentences.<br>***Line 17-19***<br>“These events resulted in a cumulative horizontal displacement of 76 m and a maximum estimated magnitude of 6.7–7.1. The average slip rate of 0.13±0.1 mm/yr suggests a quasi-periodic model with possible recurrence intervals exceeding 13,000 years” |
| 19: dextral strike-slip<br>- dextral-slip | We modified the words.<br>***Line 20***<br>“causing a dextral-slip” |
| 20: continuous faulting along<br>- several surface rupturings with large earthquakes along | We modified the sentence.<br>***Line 21-22***<br>“This study underscores the several surface ruptures with large earthquakes along the inherited mature Yangsan Fault” |
| 20: fault, the<br>- remove | |
| 25: seismic hazard assessment<br>- There is no content directly addressing SHA in the dicussion section. It cannot be the main focus of this paper. The data from this study could potentially be applicable to SHA... | We modified the sentence.<br>***Line 26-27***<br>“This study aids in understanding intraplate earthquake behavior by analyzing paleoearthquake records of the Yangsan Fault in Korea” |
| 47: fault zone complexity<br>As I mentioned in Line 13, please check the exact meaning of the "complexity" in the papers of Liu and Stein (2016) and Talwani (2017), but also | We tidy up the sentence with better clarity.<br>***Line 47-49***<br>“The faults in the intraplate region have a complex distribution rather than those in the interplate region and tend to be selectively reactivated in response to far-field stress” |

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| check the definition of the "fault zone". It could be confusing for the readers. | |
| 47-48: in irregular earthquake behavior<br>The irregularity mentioned here refer to the general area (intraplate region) rather than being limited to a specific fault. Clarify the expression.<br>- The faults in the intraplate region have complex distribution rather than those in interplate region and tend to be selectively reactivated in response to far-field stress. | |
| 49-51: To unravel the complexity of fault zones, it is essential to understand the geometry and internal structure of fault zone, along with the relationship between geometry and the in-situ stress regime, fault kinematics controlled by structure, and the correlation of these kinematics with paleoseismic data<br>- This sentence need to be rewritten. | We modified the sentence.<br>***Line 50-52***<br>"To understand the unpredictable patterns of intraplate earthquakes, it is necessary not only to collect robust paleoseismic data but also to find connections between paleoseismic data and structural features such as the relationship between geometry and the in-situ stress regime, fault kinematics controlled by pre-existing structure." |
| 53: the 2017 Pohang earthquake<br>- add the 2016 Gyeongju earthquake and related citations | We modified the sentence.<br>***Line 54-55***<br>"earthquake awareness (e.g., the 2016 Gyeongju earthquake; the 2017 Pohang earthquake; Kim et al., 2018; Woo et al., 2019)." |
| 59: , with a few exceptions<br>- except recent a few studies | We modified the sentence.<br>***Line 60-61***<br>"single trench except recent a few studies (e.g., Kim et al., 2023)" |
| 60: a pattern of intraplate earthquakes<br>- what pattern? Clarify the expression. Kim and Lee (2023) emphasize the quasiperiodic behavior of the intraplate faults... | We modified the sentence.<br>***Line 61-62***<br>"to follow the quasiperiodic behavior of intraplate" |
| 61: this pattern<br>- this pattern of an intraplate fault ??? | We tidy up the sentence.<br>***Line 62***<br>"To unravel this quasiperiodic pattern of an intraplate fault, it is" |
| 62: In this study, we try to provide clues to the pattern of earthquake behaviour.<br>- The research subject of this paper is ambiguously presented. Although it is a study focusing on the Yangsan Fault, it is phrased as if it covers the entire Korean Peninsula. | We tidy up.<br>***Line 64***<br>"we try to provide clues to the pattern of earthquake behavior of the Yangsan Fault." |
| 64: paleoseismic data<br>- paleoseismic data of the Yangsan Fault<br>; The main target of this study should be clearly described in this sentence. Additionally, briefly describe the earthquake geological significant of the Yangsan Fault. | We modified the sentence.<br>***Line 65-66***<br>"fundamental paleoseismic data on the Yangsan Fault." |
| 66: study area<br>- remove | Thanks.<br>***Line 68***<br>"Byeokgye section (Kim et al., 2022)" |
| 67: geologic maps<br>- a geological map | Thanks.<br>***Line 69*** |

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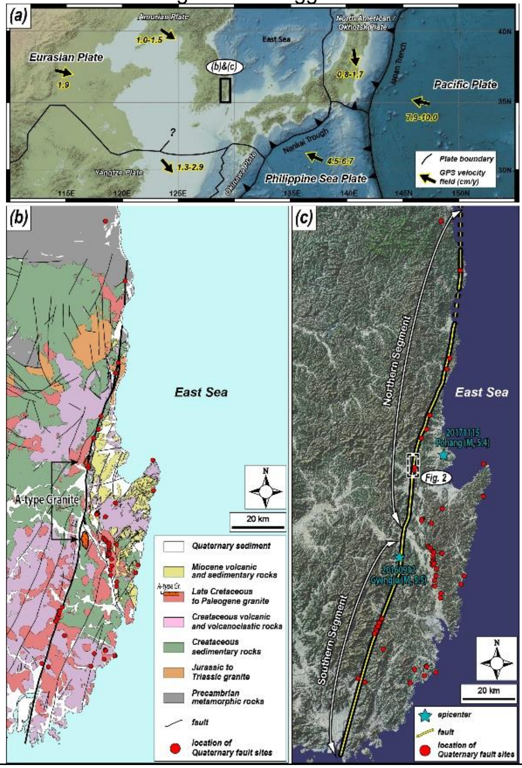
| | “create a geological map and” |
| 70: a significant tectonic feature in East Asia and Korea<br>- remove | We remove the sentence.<br>***Line 72***<br>“the Yangsan Fault. The results” |
| 71: , which is located intraplate.<br>- remove | We remove the sentence.<br>***Line 73***<br>“Quaternary rupturing patterns of the Yangsan Fault” |
| 75: Figure 1b:<br>- check legend<br>: in chronological orders,<br>Precambrian metamorphic rocks, Jurassic to Triassic granite, Cretaceous sedimentary rocks, Cretaceous volcanic and vlocanoclastic rocks, Late Cretaceous to Paleogene granite, Miocene volcanic and sedimentary rocks, and Quaternary sediment. | We modified the figure 1 as suggested.<br> |
| 80: 2 Seismotectonic setting<br>- Tectonic and geological setting | We modified the heading.<br>***Line 82***<br>“2 Tectonic and geological setting” |
| 81: Reginal seismotectonic setting<br>- Regional seismotectonic setting of Korea | We modified the subheading.<br>***Line 83***<br>“2.1 Regional seismotectonic setting of Korea” |
| 82: was<br>- is | We modified the sentence.<br>***Line 84***<br>“which was once” |

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| 86: consistency<br>- repeatedly ?? | We modified the sentence.<br>***Line 88***<br>"earthquakes have been repeatedly observed" |
| 88: maximum<br>- a maximum | We modified the sentence.<br>***Line 90***<br>"under a maximum horizontal stress of the E-W" |
| 88: in<br>- of | |
| 89: Pacific Plate<br>- Pacific and Philippine Sea plates | We modified the sentence.<br>***Line 91-92***<br>"subduction of the Pacific and Philippine Sea Plates and eastward-propagating far-field stress from India-Eurasia collision (Park et al., 2006; Kim et al., 2016; Kuwahara et al., 2021)" |
| 89-90: the far-field stress from the collision of the Indian and Eurasian plates<br>- eastward-propagating far-field stress from India-Eurasia collision | |
| 90: Kim et al., 2016<br>- add Kuwahara et al. (2021)_Tectonophysics | |
| 94: Paleoseismological<br>- Paleoseismic<br>; Use terminology consistently | We modified the sentence.<br>***Line 96***<br>"Paleoseismic studies on" |
| 95: structural line<br>- structures | We modified the sentence.<br>***Line 97***<br>"major structures in the" |
| 102-103: The reported Quaternary surface rupturing were reactivated along the pre-existing fault surface<br>- Notably, there are many records of Quaternary surface rupturings with dextral kinematics, which were reactivated along the pre-existing mature (long-lived) Yangsan fault zone.<br>103-104: with various kinematics depending on the relationship between the stress field and the geometry of the pre-existing structure<br>- please delete. It is not an important expression | We modified the sentence.<br>***Line 104-105***<br>"Notably, there are many records of Quaternary surface rupturing with dextral kinematics, which were reactivated along the pre-existing mature (long-lived) Yangsan fault zone (Cheon et al., 2020a)" |
| 104: The Yangsan Fault,<br>- This fault | We modified the sentence.<br>***Line 105-106***<br>"This fault extends > 200 km on land and is several hundred meters wide" |
| 104: one of the most significant structural lines on the Korean Peninsula<br>- delete | |
| 105: 200 km<br>- 200 km on land | |
| 106: The Yangsan Fault<br>- It | We modified the sentence.<br>***Line 107***<br>"It underwent multiple stages of deformation with" |
| 106: deformations<br>- stages of deformation | |
| 108: Yangsan Fault<br>- fault | We modified the sentence.<br>***Line 109-110***<br>"the fault is approximately 25–35 km in the Cretaceous sedimentary rocks (Chang et al., 1990) and 21.3 km in A-type alkali granite" |
| 109: granite<br>- alkali granite | |
| 110: The most reported evidence for slip sense of | We removed the sentence. |

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| Quaternary surface ruptures along the Yangsan Fault indicate that they have been reactivated with transpressional dextral slip sense under E-W to ENE-WSW oriented compressional stress fields (Kim et al., 2011; Choi et al., 2012; Jin et al., 2013; Yang and Lee, 2014; Lee et al., 2015; Kim et al., 2016; Choi et al., 2019; Cheon et al., 2020a).<br>- Repeated, delete! | |
| 115: detailed study area<br>- Byeockye section of the Yangsan Fault | We modified the subheading.<br>***Line 113***<br>"2.2 Geological settings of the Byeokgye section of the Yangsan Fault" |
| 116: granitic<br>- and granitic rocks, | We modified the sentence.<br>***Line 121-122***<br>"sedimentary, volcanic, and granitic rocks, Paleogene A-type alkaline granite, Middle Miocene sedimentary rocks, and Quaternary" |
| 116: alkaline<br>- A-type alkaline | |
| 117: sedimentary<br>- sedimentary rocks | |
| 117: Alkaline<br>- The A-type alkaline | We modified the sentence.<br>***Line 122***<br>"(Fig. 2a). The A-type alkaline granite" |
| 118: Yangsan Fault zone<br>- fault | We modified the sentence.<br>***Line 123***<br>"side of the fault in the center" |
| 120: faults<br>- the western marginal faults of the Miocene Pohang Basin | We modified the sentence.<br>***Line 125***<br>"bounded by the western marginal faults of the Miocene Pohang Basin consisting" |
| 120-121: which form the western boundary of the Pohang Basin (Middle Miocene;<br>- delete | We removed the sentence. |
| 121: Quaternary<br>- The Quaternary | We modified the sentence.<br>***Line 126***<br>"Song, 2015). The Quaternary" |
| 122: faulting of<br>- surface rupturings along<br>or movements along | We modified the sentence.<br>***Line 127-128***<br>"Quaternary surface rupturing along of the Yangsan Fault are observed in some places (Fig. 2b, 2c)." |
| 123: Figs. 2b and 2c<br>- Fig. 2b, 2c | |
| 124: Quaternary<br>- the records of the Quaternary | We modified the sentence.<br>***Line 129***<br>"reported as the records of the Quaternary surface" |
| 126: acidic<br>- felsic dike ? | We modified the sentence.<br>***Line 131***<br>"Cretaceous felsic dike and Quaternary sediment" |
| 127: reverse slip<br>- reverse slip during the Quaternary ?? | We modified the sentence.<br>***Line 132-133***<br>"reverse slip during the Quaternary" |
| 128: Byeokgye<br>- the Byeokgye site | We modified the sentence.<br>***Line 133*** |

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| | “(MRE) of the Byeokgye site occurred” |
| 128-129: after 7.5±3 ka, the optically stimulated luminescence (OSL) age of the truncated Quaternary sediments<br>- need reference | We added the reference.<br>***Line 134***<br>“Quaternary sediments (Choi et al., 2012).” |
| 129: Dangu<br>- The Dangu site | We modified the sentence.<br>***Line 134-136***<br>“The surface ruptures (N10–20°E/75–79°SE) of the two trenches at the Dangu site have geometric and kinematic features similar to those at the Byeokgye site (Lee et al., 2015)” |
| 129: Byeokgye<br>- the Byeokgye site | |
| 130-131: A fault surface (N10–20°E/75–79°SE) with geometric and kinematic characteristics similar to those of Byeokgye was found in the two trenches.<br>- rewrite | |
| 131: Byeokgye<br>- the Byeokgye site | |
| 132: cross sections<br>- exposed walls | We modified the sentence.<br>***Line 136***<br>“observed in the exposed walls indicate that” |
| 132: indicated<br>- indicate | |
| 133: Dangu<br>- the Dangu site | We modified the sentence.<br>***Line 137-138***<br>“MRE of the Dangu site using OSL dating” |
| 135: Byeokgye<br>- the Byeokgye site | We modified the sentence.<br>***Line 139-140***<br>“north of the Byeokgye site to identify further records on the Quaternary surface rupturing and attempted” |
| 135: Quaternary faults<br>- further records on the Quaternary surface rupturings | |
| 146: the trench<br>- what trench ??<br>This paper also documented the Trench 1 in this paper.. Please clarify! | We modified the sentence.<br>***Line 151-152***<br>“In the trench (Trench 1) on the fault trace, the surface rupture cuts through Quaternary sediments.” |
| 147: indicating that the fault trace is Quaternary<br>- There are too many unnecessary and repetitive sentences. | |
| 148: four sites<br>- four further sites (Trench 2 to 5) | We modified the sentence.<br>***Line 153-154***<br>“trenched it at four further sites, and identified two natural exposures (described in Appendix C).” |
| 148: and identified two natural exposures.<br>- There is no mention of the outcrop in the main text. Is there any meaning in describing it? Describe "Appendix B"<br>Be sure to clearly mention the specific details described in the appendix. | |
| 151: trench section<br>- 5 trenches ??<br>; Since the term "section" is also used for faults, I hope to distinguish it by using terms like "exposed wall" or "wall" instead in the whole manuscript. | We have changed the term trench section to exposed wall or wall throughout the manuscript as per your comment. |

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| 204: ESR<br>- Electron Spin Resonance (ESR) | We modified the sentence.<br>***Line 210***<br>"Electron Spin Resonance (ESR) dating of fault rocks" |
| 213: Palaeo<br>- Paleo | We modified the sentence.<br>***Line 221***<br>"Paleo-stress reconstruction of Quaternary rupturing is carried out using 20 slickenlines obtained from five trenches." |
| 213: Quaternary faulting was conducted using fault-slip data from 23 slickenlines in cross-sections<br>- Clearly describe how many trench locations were involved and what specifically was targeted. Additionally, only 20 slickenlines were used for paleostress reconstruction. | |
| 218: quaternary<br>- the Quaternary | We modified the sentence.<br>***Line 225***<br>"separation of the Quaternary" |
| 234-236: Many previous studies in Korea have applied the empirical relationship of the MD-moment magnitude (Mw) presented by Wells and Coppersmith (1994) (Kyung, 2010; Kim & Jin, 2006; Jin et al., 2013; Lee et al., 2017). We also estimated the maximum earthquake magnitude by applying the MD obtained from the trench to the empirical formula<br>- The logic (that this paper should use the empirical relationship from Wells and Coppersmiths simply because previous Korean researchers have used it) is somewhat difficult to accept. Please consider that because this empirical relationship is widely used internationally (whether for intraplate or interplate regions), you are using it. | We modified the sentence.<br>***Line 245-247***<br>"Many previous studies within intraplate have applied the empirical relationship of the MD-moment magnitude ($M_w$) presented by Wells and Coppersmith (1994) (e.g., Patyniak et al., 2017 in Kyrgyzstan; Suzuki et al., 2020 in Mongolia; Je et al., 2024., in China)." |
| 238-240: In addition, we used the MD-surface rupture length (SRL) empirical relationship to determine the extent to which the derived MD differed from the true displacement.<br>- As far as I know, in case of strike-slip earthquake, Wells and Coppersmith (1994) used the apparent horizontal offset for the MD (maximum displacement), not use the true displacement. Furthermore, I question the significance of the true displacement proposed by the authors. Wouldn't it be more reasonable to interpret that the horizontal offset is about 2 to 3 times the vertical offset when considering the rake? | We removed the sentence and used the horizontal displacement for magnitude estimation.<br>***Line 244-245***<br>"Thus, we used MD (horizontal displacement), which is relatively easy to obtain from outcrops and trenches and more reliable." |
| 251: fault-, fault<br>-delete | We removed the word. |
| 252: grey<br>- gray | We unified the word "grey" in both text and figures in the manuscript. |

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| ; check the word "grey" and "gray"<br>Be consistent | |
| 252, 253: fault-<br>-delete | We removed the word. |
| 263-264: Three faulting events can be analyzed in terms of the geometry of the sediments and the kinematics of the slip surface.<br>- Please summarize each earthquake event (even horizon) based on previously described contents. Apply same description flow to all trench descriptions | We added the sentence.<br>***Line 274-279***<br>"Three faulting events are interpreted based on the geometry of the sediments and the kinematics of the slip surface: (1) The first faulting event involves the rupture of all F1-F7 after the deposition of units G, H, and I before the deposition of unit F, marking the event 1 horizon. (2) The second faulting event occurred after the deposition of units E and F prior to the deposition of unit C, defining the event 2 horizon, with ruptures affecting faults F3 through F7. During this event, dextral slip along faults F5 and F6 displaced unit D. (3) The third faulting event took place after the deposition of units B and C, with rupture limited to faults F6 and F7." |
| 269: 7,675-7,821<br>- When describe a range of ages, list the older age first.<br>271: 41,955-43,292<br>- When describe a range of ages, list the older age first. | We arrange all age data in chronological order (older, first).<br>***Line 282-283***<br>"1803BYG-01-C and 1803BYG-02-C are 38,420–36,897 and 45,670–43,802 Cal yr BP, respectively" |
| 290: Table 1.<br>- The way this table is presented makes it appear as the units A, B, C, D.... of each trench are all being compared. This needs to be revised.<br>293: Table 2.<br>- This table is difficult to read. Organize it according to the stratigraphy of each trench wall. | We've combined Tables 1 and 2 for better readability. (Table 1 below) |

Table 1

| Unit | Features | Age | | |
|---|---|---|---|---|
| | | Age (ka) | Dating method | Sample number |
| **Trench 1** | | | | |
| A | Brown fine sand, lens shape in unit B, coarsening upward in the bottom (silt to fine sand) | 1.3 ± 0.1 | OSL | 01 |
| B | Dark brown cobble, fine sand matrix, poor roundness, fining upward in clast (cobble to pebble) and matrix (sand to fine sand), the youngest unit cut by fault | 9.0 ± 1.0 | OSL | 02 |
| | | 10 ± 1 | OSL | 03 |
| | | 4.9 ± 0.3 | OSL | 05 |
| | | 3.2 ± 0.2 | OSL | 06 |
| | | 8.1 ± 0.3 | OSL | 14 |
| C | Brown medium sand with cobble, good roundness and sorting compared to unit b, pinch out in footwall, cover the pre-existing fault core | 17 ± 1 | OSL | 13 |
| D | Light brown sand with pebble, good roundness and sorting despite adjacent fault, captured by a triangular shape, with fault surface | | - | |
| E | Grey fine sand & brown medium sand, mixing with grey and brown parts, SSDS (load structure dominated; load cats, pillar structure, sand dike, disturbed structure, structureless sediments) | 146 ± 8 | $pIRIR_{225}$ | 04 |
| | | 143 ± 7 | $pIRIR_{225}$ | 09 |
| | | 164 ± 8 | $pIRIR_{225}$ | 10 |
| F | Greyish-white medium sand | | - | |
| G | Grey fine sand with granule, SSDS (intrusive structure dominated; ball and pillow, flame structure, sand dike) | 151 ± 8 | $pIRIR_{225}$ | 08 |
| | | 155 ± 8 | $pIRIR_{225}$ | 11 |
| H | Brown gravelly fine sand, moderate roundness and sorting | 177 ± 7 | $pIRIR_{225}$ | 07 |
| | | 142 ± 7 | $pIRIR_{225}$ | 12 |
| I | Greyish-white gravelly fine sand, matrix derived from granite that basement rock | | - | |

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| **Trench 2** | | | | |
| A | Reddish brown cobble deposits, A subangular clast composed of granitic and sedimentary rocks with a maximum diameter of 40 cm, poor sorting, charcoal in the bottom, cover the pre-existing fault core | 3.2 ± 0.3 | OSL | 05 |
| | | 3.4 ± 0.4 | OSL | 06 |
| | | 19 ± 1 | OSL | 07 |
| B | Light grey silt-light yellowish brown fine sand, interbedded two layers, cut by main fault surface | | - | |
| **Trench 3** | | | | |
| A | Dark brown fine sand-silt | | - | |
| B | Light brown boulder-cobble deposits, colluvial deposits from mountain slopes, moderate roundness, decreasing the clast size toward the west, cover the main fault surface | 6.4 ± 0.4 | OSL | 10 |
| C | Brown pebble deposits, poor roundness and sorting, brown sand matrix, the youngest unit cut by fault | | - | |
| D | Yellowish-brown pebble deposits, colluvial wedge, triangular shaped, angular to subangular clast, poor sorting in bottom, fining upward, sand content increases with distance from the main fault surface | 137 ± 3 | $pIRIR_{225}$ | 08 |
| E | Brown cobble-pebble deposits, subangular clast, poor sorting, intercalated fine sand to silt | 173 ± 6 | $pIRIR_{225}$ | 02 |
| | | 175 ± 5 | $pIRIR_{225}$ | 03 |
| F | Brown sand-fine sand | | - | |
| G | Brown pebble deposits, subangular clast, poor sorting, clast composed of granitic, volcanic, sedimentary rocks | | - | |
| H | Brown sand-fine sand | | - | |
| **Trench 4** | | | | |
| A | Brown fine sand, have a charcoal | 0.15±0.01 | OSL | 07 |
| | | 0.15±0.01 | OSL | 08 |
| B | Dark brown cobble deposits-sand, colluvial deposits from mountain slopes, subangular clast, poor sorting, the youngest unit cut by fault | 1.3 ± 0.1 | OSL | 05 |
| | | 1.2 ± 0.1 | OSL | 06 |
| | | 5.9 ± 0.4 | OSL | 09 |
| C | Light brown boulder deposits-sand, matrix is coarse sand to sand, angular clast, poor sorting, clast mainly composed of granite, the maximum diameter of a clast is ~ 120 cm | | - | |
| D | Brown sand-fine sand, fining upward | | - | |
| E | Brown cobble deposits-coarse sand, alternating sand and gravel, average diameter of clast is 2-5 cm, subangular to angular, moderate sorting | | - | |
| F | Light brown sand-fine sand | | - | |
| **Trench 5** | | | | |
| A | Reddish brown pebble deposits, A subangular clast composed of granitic, sedimentary, volcanic rocks with a maximum diameter of 15 cm, good sorting, matrix-supported | - | | |
| B | Reddish brown fine sand-slit, weak horizontal bedding, the youngest unit cut by fault, no truncation or deformation after MRE. | 2.8 ± 0.1 | OSL | 03 |
| | | 2.6 ± 0.1 | OSL | 04 |
| C | Reddish brown cobble-pebble deposits, fine sand matrix, clast composed of granitic, sedimentary, volcanic rocks, angular to sub-angular clast, poor sorting, containing clasts almost 40%. | 10 ± 1 | OSL | 01 |
| | | 4.8 ± 0.2 | OSL | 02 |
| D | Light bluish-grey pebble deposits, light grey fine sand matrix, the maximum diameter of a clast is ~ 20 cm, clast composed of sedimentary, volcanic rocks, angular to sub-angular clast, poor sorting | - | | |
| E | Light yellowish brown pebble deposits, A slit near the fault surface gradually increases in grain size as it moves away, changing to a pebble deposit, angular to sub-angular clast, good sorting | - | | |

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| 302: The details of all data are in Kim and Lee (2023)<br>- This data is already published by Kim and Lee (2023). If that, consider that simply cite the ESR results described throughout the paper. The results are currently presented as if these were newly analyzed results from this study. | We use the ESR dating results reported by Kim and Lee (2023) and mention this in Chapter 3.2.4. In addition, we have labeled the location and age on all trench sketches to indicate that the ages used are from trenches in our study.<br>***Line 217-219***<br>"In our study, we use the ESR ages of samples from trenches and fault sites in the study area reported by Kim and Lee (2023) to estimate the number of earthquakes." |
| 303: 4.2.2 Trench 2<br>- I repeat. The descriptions of faults for each trench need to be rewritten in a more concise and systematic manner. | We rewrote the description of each trench to be concise and in a consistent order as follows.<br>1, location information, 2. trench neighborhood topography, 3. brief exposed wall, 4. features of the pre-existing fault core, 5. Quaternary sediment or structural features, 6. geometric relationship of rupture to sediments, 7. estimation of the number of faulting events, and 8. age dating results (OSL, IRSL, radiocarbon dating results -> interpretation->ESR age->interpretation of ESR age). Also, we have reduced the amount of information on bedrock fault cores and focused more on Quaternary surface rupture.<br><br>***Line 316-345***<br>**4.2.2 Trench 2**<br>Trench 2 is located on the main lineament 0.8 km north of Trench 1 (Fig. 2c), within a colluvial area where fault scarp extend continuously along the main lineament to the south and north. Just north of Trench 2, the transition to an alluvial fan is clearly visible where the mountain ridge meets the main lineament. The 25-m wide valley surface contains partially developed colluvial sediments and deposits from small streams and gullies. Two Quaternary deposits are observed in Trench 2, along a low-angle Quaternary slip surface (N02°E/38°SE) intersecting the Quaternary deposits on the exposed wall (Fig. 4). The minimum 6-m-wide fault core of the hanging wall is composed of mature fault rocks. The fault core is divided into yellow and bluish-grey (Fig. 4). Foliation developed within the yellow fault core, which abutted the Quaternary slip surface in the upper part of the wall. The Quaternary slip surface cuts unit B, displaying thrusting of the hanging wall's pre-existing fault core, while unit A overlies both features. Unit A has a loose matrix and relatively low consolidation compared to the underlying unit B and overlies the pre-existing fault core (Table 1). The slickenline on the Quaternary slip surface shows a dextral slip with a minor reverse component. Only one faulting event is recognized, in which the Quaternary slip surface cuts through unit B, and unit A overlies it (Figs 5b and 5d).<br>The OSL ages of unit A, which covers the rupture, are 3.4±0.4 ka (1810NSR-06) and 3.2±0.3 ka (1810NSR-05) at the southern wall and 19±1 ka (1810NSR-07) at the northern wall (Table 1). The radiocarbon ages of the charcoal in unit A are 291–0 and 304–0 cal yr BP (Table 2), making them much younger than the OSL age from unit A. Radiocarbon dates do not indicate when the charcoal is deposited with the sediment but when the tree died after being rooted in the ground. The OSL results indicate a depositional age of 3.4±0.4 ka for unit A, which is not cut by the rupture, so the MRE of the surface rupture in Trench 2 is interpreted to be before 3.4±0.4 ka. The ESR ages obtained from the fault gouge are higher than the depositional ages of the sediments cut by the rupture (Table 3). The ESR ages suggest that the quartz ESR signal in the fault gouge is not fully initialized during faulting. Nevertheless, the ESR ages roughly cluster into four periods: 790±60 ka (1810NSR-01-E), 407±37 ka (1810NSR-02, 03-E), 350±49 ka (1810NSR-05, 06-E), and 261±48 ka (1810NSR-09-E).<br>To estimate the thickness of the Quaternary sediments and the cumulative vertical displacement of the Quaternary slip, drilled sediments are sampled from the footwall along the Quaternary slip surface (Fig. D1). The Quaternary sediments extend to a depth of approximately 32.8 m, underlain by a granite wash (1.2 m thick) of Paleogene A-type alkali granite, and a subsequent fault damage zone of the granite exists at its base (Fig. D1). Therefore, the vertical separation caused by the Quaternary rupture in Trench 2 is at least 34 m. However, the vertical separation is a paleo-topographic relief difference that may have been caused by the strike-slip movement of the Quaternary slip. Cosmogenic $^{10}$Be-$^{26}$Al isochron dating of the granite wash underlying the Quaternary sediments yielded a burial age of 2,871±593 ka, indicating that the thick Quaternary sediments started to be deposited after 2,871±593 ka (Table 4). |
| 304: was<br>- is | We modified the sentence.<br>***Line 317***<br>"Trench 2 is located on the main lineament 0.8 km north of Trench 1 (Fig. 2c)" |
| 304: 1.8<br>- 0.8 | |
| 304: Byeokgye site<br>- Trench 1 | |

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| 312-313: This indicated warping of the main fault surface along the pre-existing structural grains and foliation (Figs. 4b and 4d).<br>- It is difficult to agree. Isn't it possible that the old fault rock in the vicinity was disturbed by the Quaternary slip event? | We removed the sentence. |
| 314: Bluish-gray fault<br>- Please ensure that the terminology used in the figures is consistent with the terminology used in the text | We unified the word "grey" in both text and figures in the manuscript. |
| 315: four to six<br>- Describe it accurately | We removed the sentence. |
| 317: strike<br>-delete | We removed the word. |
| 318: revealed<br>-show | We removed the sentence. |
| 318: strike<br>-delete | |
| 318: had<br>- has | |
| 319: had an irregular boundary with<br>- overlies | We modified the sentence.<br>***Line 325-326***<br>"unit B and overlies the pre-existing" |
| 320: did not reach unit A<br>- is covered by unit A | We modified the sentence.<br>***Line 327-328***<br>"Only one faulting event is recognized, in which the Quaternary slip surface cuts through unit B, and unit A overlies it" |
| 331: cored<br>- drilled? | We modified the sentence.<br>***Line 338-339***<br>"Quaternary slip, drilled sediments" |
| 333: Paleogene alkali granite<br>- the A-type alkali granite<br>; Be consistent | We modified the sentence.<br>***Line 340***<br>"Paleogene A-type alkali granite" |
| 335: was<br>- is | We modified the sentence.<br>***Line 342***<br>"Trench 2 is at least 34 m" |
| 340: Figure 4<br>- I suggest placing the sketch immediately after the photomosaic. This will improve readability | We changed the order of the photos and sketches of all the trenches as you suggested and removed the fault core 1 and 2 in the figure 4. |
| 341: southern wall.<br>(d) southern wall<br>; The extent of fault core 1 in this figure is somewhat confusing. | |

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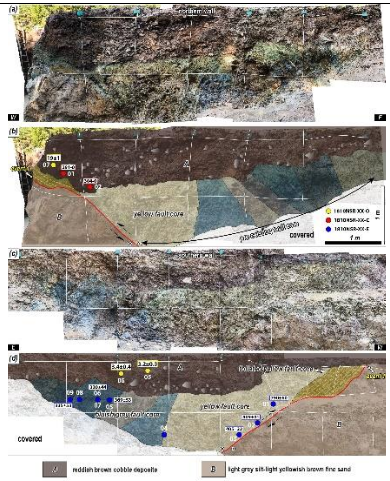
| |  |
| 342: results<br>- results of granite wash at Trench 2 | We modified the Table 4 caption.<br>***Line 351***<br>"Table 4. Cosmogenic $^{10}$Be-$^{26}$Al isochron burial dating results of granite wash at Trench 2" |
| 348: Trench 3<br>- I repeat. The descriptions of faults for each trench need to be rewritten in a more concise and systematic manner. | We rewrote the description of each trench to be concise and in a consistent order as follows.<br>1, location information, 2. trench neighborhood topography, 3. brief exposed wall, 4. features of the pre-existing fault core, 5. Quaternary sediment or structural features, 6. geometric relationship of rupture to sediments, 7. estimation of the number of faulting events, and 8. age dating results (OSL, IRSL, radiocarbon dating results -> interpretation->ESR age->interpretation of ESR age). Also, we have reduced the amount of information on bedrock fault cores and focused more on Quaternary surface rupture.<br><br>***Line 357-381***<br>**4.2.3 Trench 3**<br>Trench 3 is located on the main lineament extending 1.7 km north of the Trench 2 (Fig. 2c), within a cultivated field next to a wide road at the mouth of a broad basin. Fault scarps along the main lineament extend both south and north of the Trench 3. This trench marks the northernmost point where the transition to the alluvial fan is observed where the mountain ridge meets the main lineament; beyond this point, fault scarps continue to develop on the alluvial fan surface. Eight Quaternary sedimentary units and three fault splays are identified in the trench wall (Fig. 5, Table 1). The hanging wall of the Quaternary slip zone, which cut through Quaternary sediments, is composed of a pre-existing fault core. Excavation revealed a fault core at least 20 m wide. The fault gouge zone that cut the Quaternary sediments is narrower than 5 cm at the bottom of the wall and widened to 40 cm at the top of the wall; it is divided into a greyish-white gouge zone and a red gouge zone by color and slip surface. The red fault gouge zone is almost entirely composed of clay; however, there are numerous uncrushed quartz and rock fragments within the grayish-white gouge zone. The characteristics of the eight units are shown in Table 1. Unit D is a colluvial wedge that indicates a paleo-earthquake (Fig. 5, Table 1). Brown sand to fine (units F and H) and brown gravel (units C, E, and G) deposits are in the trench wall. These features can be attributed to environmental factors, such as deposition due to repeated rainfall, flooding, or seismic events due to repeated seismic motion. The Quaternary slip zone cuts through unit C, including unit D, a colluvial wedge, and is covered by unit B. The slickenline observed on the fault splays indicates a dextral slip with a small reverse component. There are at least two estimated faulting events in this exposed wall: event 1, which formed a colluvial wedge, and event 2, which cut the colluvial wedge (Fig. 5).<br>The pIRIR$_{225}$ ages of sample 1903NR1R-02 and 03-O from unit E at the southern wall are 173±6 ka and 175±5 ka, respectively. In contrast, the pIRIR$_{225}$ age of 1903NR1R-08-O from unit D, which is the colluvial wedge that directly indicates the timing of a faulting event, shows |

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| | that the deposit formed at 137±3 ka (Table 1). Additionally sample 1903NR1R-10-O from unit B, which covers the rupture, is dated as 6.4±0.4 ka. These findings suggest that the first surface rupture occurred at 137±3 ka, as indicated by the colluvial wedge, and the next surface rupture occurred before 6.4±0.4 ka indicated by event 2 horizon. The youngest ESR age for the fault gouge is 409±52 ka (1903NR1R-02-E, Table 3). However, since the quartz ESR signal in the fault zone may not fully reset during faulting, this age implies that the faulting event occurred at or after 409±52 ka. The ESR ages cluster into two time periods: 417±59 ka (1903NR1R-01, 02-E), 702±123 ka (1903NR1R-03-E). |
| 349: was<br>- is<br>349: 3.5<br>-1.7<br>349: Byeokgye site<br>- Trench 2 | We modified the sentence.<br>***Line 358***<br>"Trench 3 is located on the main lineament extending 1.7 km north of the Trench 2" |
| 354-355: off-white fault zone and a red fault zone<br>- ?? | We modified the sentence.<br>***Line 365***<br>"divided into a greyish-white gouge zone" |
| 356: fault-<br>-delete | We removed the word. |
| 356: brecciated zones<br>- where in the figure? | We removed the sentence. |
| 377: 4.2.4 Trench 4<br>- I repeat. The descriptions of faults for each trench need to be rewritten in a more concise and systematic manner. | We rewrote the description of each trench to be concise and in a consistent order as follows.<br>1, location information, 2. trench neighborhood topography, 3. brief exposed wall, 4. features of the pre-existing fault core, 5. Quaternary sediment or structural features, 6. geometric relationship of rupture to sediments, 7. estimation of the number of faulting events, and 8. age dating results (OSL, IRSL, radiocarbon dating results -> interpretation->ESR age->interpretation of ESR age). Also, we have reduced the amount of information on bedrock fault cores and focused more on Quaternary surface rupture.<br>***Line 388-408***<br>4.2.4 Trench 4<br>Trench 4 is situated on a NE-striking eastern branch lineament from the main lineament, which stretches 2.8 km north of the Trench 3 (Fig. 2c). South of Trench 4, a continuous dextrally deflected stream follows the branching lineament, with smaller displacements identified further north. Trench 4 lies at the edge of an alluvial fan near a hillslope, with two features separated by a stream. Within the trench wall, five Quaternary sedimentary units are cut by a surface rupture (Fig. 6, Table 1). The hanging wall of the Quaternary fault splay includes a pre-existing fault core at least 5 meters wide at the time of excavation. Adjacent to the Quaternary sediments, a 20-cm-wide fault gouge zone developed, characterized by yellowish-brown and reddish-brown gouges. Units A and B exhibit horizontal to sub-horizontal bedding, while the bedding of units C-F tilts westward, with dips of up to 50° near the surface rupture, becoming shallower to the west (Fig. 6, Table 1). The difference in bedding orientations indicates an angular unconformity between unit B and units C–F. A surface rupture, covered by unit A, cuts through all of units C-F, including the unconformity, but does not extend through all of unit B. The slickenlines observed on the fault splay indicating dextral slip with a minor reverse component. At least two faulting events are inferred from the exposed wall: the first faulting event (PE) caused the tilting of units C–F after deposition (event 1 horizon), and MRE occurred during the deposition of unit B, following the formation of the angular unconformity (Fig. 6).<br>We collected five samples from the northern wall of units A and B. The OSL age of 5.9±0.4 ka was obtained from 2009UGR-09-O, which is cut by the rupture. For the remaining four samples that are not cut by the rupture, the oldest OSL age is 1.3±0.1 ka, recorded for 2009UGR-05-O (Table 1). Additionally, samples were collected from units F (2009UGR-01-C) and A (2009UGR-02-C) for radiocarbon dating (Table 2). The radiocarbon age of the charcoal from 2009UGR-02-C is 160±30 cal yr BP, which aligns with the OSL age of 0.15±0.01 ka for the sediment containing the charcoal (2009UGR-07-O), and strongly indicating that unit A was deposited at this time. Based on the the comprehensive dating analyses, the MRE for this trench occurred between 5.9±0.4–1.3±0.1 ka, as the faulting event took place during the continuous deposition of unit B. |
| 378: was<br>- is<br>378: trending | We modified the sentence.<br>***Line 389-390***<br>"Trench 4 is situated on a NE-striking eastern branch lineament from the main lineament, which stretches 2.8 km north of the Trench 3" |

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| - striking | |
| 378: branch<br>- eastern branch | |
| 378: 6.3<br>- 2.8 | |
| 378-379: Byeokgye site<br>- Trench 3 | |
| 380: main fault surface<br>- Quaternary fault splay | We modified the sentence.<br>***Line 392-393***<br>"The hanging wall of the Quaternary fault splay includes a pre-existing fault core at least 5 meters wide at the time of excavation" |
| 380: that cut the Quaternary sediments contained<br>- is | |
| 380, 381: was<br>- is | |
| 388: sections<br>- parts | We removed the sentence. |
| 393: cross-section<br>- exposed wall | We modified the sentence.<br>***Line 399-400***<br>"from the exposed wall: the first faulting event" |
| 402: 1.3±0.1–5.9±0.4<br>- When describe a range of ages, list the older age first. | We modified the sentence.<br>***Line 408***<br>"occurred between 5.9±0.4–1.3±0.1 ka" |
| 407: 4.2.5 Trench 5<br>- I repeat. The descriptions of faults for each trench need to be rewritten in a more concise and systematic manner. | We rewrote the description of each trench to be concise and in a consistent order as follows.<br>1, location information, 2. trench neighborhood topography, 3. brief exposed wall, 4. features of the pre-existing fault core, 5. Quaternary sediment or structural features, 6. geometric relationship of rupture to sediments, 7. estimation of the number of faulting events, and 8. age dating results (OSL, IRSL, radiocarbon dating results -> interpretation->ESR age->interpretation of ESR age). Also, we have reduced the amount of information on bedrock fault cores and focused more on Quaternary surface rupture.<br><br>***Line 415-432***<br>**4.2.5 Trench 5**<br>Trench 5 is located 40 m north of Trench 4. Because of its proximity, Trench 5 shares identical topographic characteristics with Trench 4, except that it lies on the margins of a hillslope instead of on an alluvial fan. The trench wall contained five quaternary sedimentary units, cut by one fault splay (Fig. 7). The overall appearance of the exposed wall is similar to that of Trench 4. The hanging wall of the fault splay that cut the Quaternary sediments consisted of a pre-existing fault core at least 20 m wide. Where it abuts the Quaternary sediments, a 10 cm wide light grey fault gouge developed, which changed to a yellowish grey fault gouge with yellow clay mixed toward the top. Units A-C show subhorizontal bedding, units D and E show westward-dipping bedding, and there is an angular disconformity between units C and D. Trenches 4 and 5 are almost the same because they are adjacent, with units A-C in Trench 5 matching units A, B in Trench 4 and units D, E in Trench 5 matching units C-F in Trench 4. The reddish-brown sediments in the upper part of Trench 5 appear to be thicker than in Trench 4 because it is the tip of a hillslope. The Quaternary fault splay cut unit C but failed to cut unit B. The slickenline observed on the high-angle Quaternary fault splay indicated a dextral slip with a small reverse component. At least two faulting events are estimated, based on the same angular unconformity as in Trench 4. Event 1 caused units D and E to tilt, which cut them (event 1 horizon, Fig 7). Event 2 occurred during the deposition of unit C, which failed to cut into unit B.<br>The OSL ages on the southern wall of 2010UGR-03-O and 04-O from unit B are 2.8±0.1 and 2.6±0.1 ka, respectively, and those of 2010UGR-01-O and 02-O from unit C are 10±1 and 4.8±0.2 ka, respectively (Table 1). The fault splay is cutting through unit C and failing to cut through unit B. Therefore, trench 5 yielded a tighter MRE range of 4.8±0.2–2.8±0.1ka than the MRE of Trench 4. |
| 414: A 20 cm-wide fissure filling<br>- Where is the fissure filling in the figure? | We removed the sentence. |
| 428: the trench 5 section of the (a) northern and (b) southern walls. | We modified the caption.<br>***Line 434-436*** |

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| - (a) northern and (b) southern walls of the Trench 5. | "Figure 7: Photomosaic of (a) northern and (b) southern walls of the Trench 5. The colored circles represent samples for age dating. Detailed sketch of (c) northern and (d) southern walls of the Trench 5. Grey lines indicate a 1 × 1 m grid. The numbers in the yellow, red, and blue boxes represent OSL and IRSL (ka), radiocarbon (cal yr BP), and ESR (ka) dating results, respectively." |
| 429: the trench 5 section of the (c) northern and southern walls<br>- (d) | |
| 431: 4.3 Paleo-stress reconstruction<br>- In the text, Quaternary faults and bedrock faults are described separately, but the figures only present the results for the Quaternary faults. It would be better to state in the text that the focus is on the striations indicating Quaternary faults, without considering the bedrock faults. | We removed the sentence and focused more on the Quaternary fault as you suggest.<br>***Line 438-444***<br>"The 20 slickenlines found in the trench were divided into those in the main fault surface that cut the Quaternary sediments and those in the pre-existing fault core. For the reconstruction of the paleo-stress field, twenty kinematic data along with the geometry of the fault planes and slickenlines were collected and analyzed using Wintensor S/W (v.5.8.5) (Delvaux & Sperner, 2003). Based on the slickenlines of the main fault surface, the analysis yielded a maximum horizontal stress ($\sigma_{Hmax}$) in the ENE-WNW direction (R´=1.62; Delvaux et al., 1997; Fig. 8), which agrees with the current stress field on the Korean Peninsula (Kim et al., 2016). The reconstructed paleo-stress indicated that the dextral strike-slip with a small reverse component identified in the main fault surface occurred in an ENE-WSW strike-slip stress regime." |
| 432: The slickenlines<br>- how many? | |
| 440: ENE-WSW compressional stress regime<br>- The stress ratio and direction of the principal axes indicate a strike-slip stress setting, not a compressional environment. | |
| 446-447: In our previous study<br>- what is your previous study? | We modified the sentence.<br>***Line 450-451***<br>"In the previous study by Lee at al. (2016), the horizontal displacement" |
| 447: true displacement<br>- Consider whether this is truly meaningful. Also, think about focusing on describing the vertical and horizontal displacements. | We used horizontal displacement except for true displacement, as per your good suggestion. Since the study area is a strike-slip fault, your suggestion is reasonable. So, we modified the paragraph.<br>***Line 450-463***<br>"The results calculated using the marker, vertical separation of each trench, and Eq. (B1) are listed in Table 5. In the previous study by Lee et al. (2016), the horizontal displacement of the MRE at the Dangu site is determined to be 2.55 m. For each surface rupturing event in Trench 1, the horizontal displacement per event according to the event horizon is 0.9–1.05 m, and the horizontal displacement of the MRE is 1.72 m. Using the bedrock and Quaternary sediments unconformity identified by corings in Trench 2 as a marker, the cumulative horizontal displacement is 76 m. The MRE cutting the colluvial wedge in Trench 3 has a horizontal displacement of 2.85 m. However, when considering the overall interpretation, only the MRE and AE, but not the PE, are recognized in Trench 3 (Figs. 5 and 9). The displacement cutting the colluvial wedge likely reflects the displacement of the missing PE as well as the MRE, which is supported by the long interval between the wedge (unit D) and the deposit covering the wedge (unit B). Thus, it is reasonable to exclude the calculated displacement as it is unlikely to be the displacement of the MRE. The horizontal displacement of the MRE in Trench 4 and 5 are 0.82 m and 2.21 m, respectively, using the lower boundary of units B and C as markers. Combining the results from each trench, the horizontal displacement of MRE in the study area is 0.82–2.55 m and the cumulative horizontal displacement is 76 m. The horizontal displacement per event is similar, between 0.9–1.05 m for PE and AE (event 1, 2), but the trench shows a higher displacement for the MRE (event 3)." |
| 447: faulting<br>- surface rupturing | |
| 448: was<br>- is | |
| 451: had<br>- has | |
| 456, 458: was<br>- is | |
| 459: showed<br>- shows | |
| 461, 462: was<br>- is | |
| 463-464: suggesting that the actual surface rupture length in the study area exceeds 7.6 km, although this was not confirmed by the current topography<br>- Of course, the 7.6 km you found is a conservative estimate, reflecting the limitations of paleoseismological research | We deleted the sentence. |
| 464-471: The earthquake magnitude was estimated from the seismic SSDs in the trench cross-sections (units E and G in Trench 1; unit F in Trench 3). In unit E, the clastic dike varied in size | We tidy up the sentence.<br>***Line 465-467***<br>"Seismic SSDs such as the 20-50 clastic dike and 30 cm ball-and-pillow structure observed in the exposed wall (units E and G in Trench 1; unit F in Trench 3), serve as indirect evidence indicating an earthquake of at least magnitude 5.5 (Atkinson et al., 1984)." |

<table>
<tr>
<td>from approximately 20 to 50 cm, whereas in unit G, a ball-and-pillow structure of more than 30 cm developed (Song et al., 2020; Ha et al., 2022). Atkinson et al. (1984) reported that liquefaction phenomena, including SSDs above a certain size in sediments of shallow lake or fluvial origin, occur when the minimum earthquake magnitude exceeds 5.5. Based on this, the estimated earthquake magnitude of these SSDs structures may vary depending on the depositional environment and substrate characteristics. However, it was estimated to be at least 5.5, which is consistent with the magnitude of the inferred empirical relationship.<br>- The conclusion of this section is that the SSDS is also indirect evidence indicating at least a magnitude 5.5. So, write it concisely and clearly.</td>
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<td>472: Table 6.<br>- I think that the rake angles on slickensides are depend on the slip surface attitude (strike and dip). For example, in case of Trench 1, the rake angles of 17 to 56 are really measured on a slip surface with no attitude change? I think that as the dip angle decrease, the rake value will increase.<br>So, the authors need to focus on the rake observed on high-angle splay surfaces rather than the rake formed in low-angle splay surfaces near the ground-surface.</td>
<td>We changed the Table 6.
<table>
<tr><th></th><th></th><th>$S_v$ (m)</th><th>α (°)</th><th>γ (°)</th><th>$S_t$ (m)</th><th>$S_h$ (m)</th></tr>
<tr><td rowspan="2">Dangu[a]</td><td>MRE (event 3)</td><td>0.67</td><td>79</td><td>15</td><td>2.64</td><td>2.55</td></tr>
<tr><td>Marker</td><td colspan="5">Unit D</td></tr>
<tr><td rowspan="6">Trench 1[b]</td><td>MRE (event 3)</td><td>0.49</td><td>69</td><td>17</td><td>1.8</td><td>1.72</td></tr>
<tr><td>Marker</td><td colspan="5">Unit C</td></tr>
<tr><td>PE (event 2)</td><td>0.31</td><td>75</td><td>17</td><td>1.1</td><td>1.05</td></tr>
<tr><td>Marker</td><td colspan="5">Unit G</td></tr>
<tr><td>AE (event 1)</td><td>0.22</td><td>53</td><td>17</td><td>0.94</td><td>0.9</td></tr>
<tr><td>Marker</td><td colspan="5">Unit H</td></tr>
<tr><td rowspan="2">Trench 2</td><td>Cumulative displacement</td><td>34</td><td>38</td><td>36</td><td>94</td><td>76</td></tr>
<tr><td>Marker</td><td colspan="5">Quaternary deposits thickness</td></tr>
<tr><td rowspan="2">Trench 3</td><td>MRE (event 3)</td><td>1.1</td><td>42</td><td>30</td><td>3.29</td><td>2.85</td></tr>
<tr><td>Marker</td><td colspan="5">Unit D</td></tr>
<tr><td rowspan="2">Trench 4</td><td>MRE (event 3)</td><td>0.25</td><td>86</td><td>17</td><td>0.86</td><td>0.82</td></tr>
<tr><td>Marker</td><td colspan="5">Unit B</td></tr>
<tr><td rowspan="2">Trench 5</td><td>MRE (event 3)</td><td>0.8</td><td>84</td><td>20</td><td>2.35</td><td>2.21</td></tr>
<tr><td>Marker</td><td colspan="5">Unit C</td></tr>
</table>
</td>
</tr>
<tr>
<td>478: determined<br>- determine</td>
<td>We modified the sentence.<br>Line 474<br>“We determine the MRE”</td>
</tr>
</table>

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| 480: trench section (see the heading 4.1)<br>- each trench<br>480: were<br>- are | We modified the sentence.<br>***Line 476***<br>“kinematics in each trench (see the heading 4.1). The results for each trench are synthesized” |
| 481: in the study area<br>- along the Byeokgye section<br>482: was<br>- is<br>482: 2.8±0.1–3.2±0.2 ka<br>- When describe a range of ages, list the older age first. | We modified the sentence.<br>***Line 477-478***<br>“earthquakes along the Byeokgye section (Fig. 9). First, the MRE is 3.2±0.2–2.8±0.1 ka,” |
| 484-485: in the study area, as determined from the Dangu site and Trench 1<br>- along the studied section<br>485-486: The timings of the remaining two prior earthquakes, excluding the MRE, were quantified by combining the age and interpretation of each trench<br>- Futhermore<br>486: which was determined using<br>- based on | We modified the sentence.<br>***Line 480-481***<br>“three faulting events may have occurred along the studied section. Furthermore, the penultimate earthquake (PE) occurred in 75±3–17±1ka, based on the youngest age of the PE (unit C)” |
| 488: was<br>- is<br>488-489: age of the lowermost sediments cut by the fault in Trench 1 and the colluvial wedge<br>- paleoseismic interpretation | We modified the sentence.<br>***Line 482-483***<br>“The antepenultimate earthquake (AE) is from 142±4–137±3ka, constrained by the paleoseismic interpretation in Trench 3.” |
| 489: suggested<br>- suggest<br>490: separate<br>- separate older | We modified the sentence.<br>***Line 483-484***<br>“error range suggests at least three separate older earthquakes at 817±10, 404±10, and 245±37 ka” |
| 491: as<br>- because of the possibility that | We modified the sentence.<br>***Line 485-486***<br>“faulting event because of the possibility that the ESR signal” |
| 492-493: Nevertheless, the faulting patterns recognized from clustering in several trenches indicated that the study area experienced at least three earthquakes in addition to those that cut Quaternary sediments.<br>- This sentence completely disregards the ESR dating results. I suggest rewriting it to take the ESR dating results into account | We modified the sentence.<br>***Line 486-487***<br>“Nevertheless, clustered faulting patterns at seven sites suggest that the study area had at least six earthquakes during the Quaternary.” |
| 495: Figure 9<br>- Late Pleistocene, Middle Pleistocene, Early Pleistocene<br>; use the upper case / Trench 1, Trench 2, ............ | We modified the figure 9.<br>Figure 9 |

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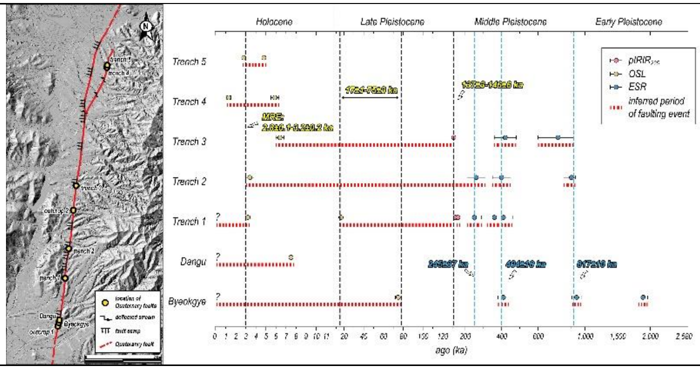
| |  |
| 498: Quaternary<br>- Specify the timing (or period) more clearly | We have presented two slip rates: one from the Late Pleistocene to the Holocene and one during the Quaternary, which is why we refer to it as the Quaternary in the subheading. |
| 499: a period<br>- a certain period | We modified the sentence.<br>***Line 493***<br>“fault over a certain period” |
| 501: age<br>- earthquake timing | We modified the sentence.<br>***Line 495***<br>“based on the earthquake timing and” |
| 503: section<br>- walls | We modified the sentence.<br>***Line 496-517***<br>“We calculated slip rates from three trenches spanning different periods: Late Pleistocene to Holocene (Trench 1), Quaternary (Trench 2), and Middle Pleistocene to Holocene (Trench 3). In Trench 1, we derived a slip rate of 0.12-0.14 mm/yr based on the horizontal displacement of event 3 (MRE) of 1.72 m and the 13.8±1.2 ka time interval between events 3 and 2 (time gap between units B and C; Table 1). For Trench 2, borehole data revealed a slip rate of 0.02-0.03 mm/yr, calculated from the cumulative horizontal displacement of 76 m and the cosmogenic $^{10}Be$-$^{26}Al$ isochron burial age of 2.87±0.59 Ma from the lowermost Quaternary deposits. In Trench 3, we calculated a slip rate of 0.02 mm/yr using the 2.85 m horizontal displacement of the event that cut the colluvial wedge (unit D) and the 130.6±3.4 ka time interval between events (time gap between units B and D).<br>Considering the age of the deposits, the slip rate of 0.12-0.14 mm/yr from Trench 1 represents movement during the Holocene, while the rates from Trenches 2 and 3 may represent cumulative slip rate (0.02 mm/yr) throughout the Quaternary. As noted in the method section (3.3), there are uncertainties in obtaining slip rates from 2D trenches alone on strike-slip faults such as the study area. In particular, the discontinuous distribution of Quaternary sediments may have led to a misestimation of the slip rate. There are two distinct types of sediments in the trench wall: (1) light brown, relatively coarse-grained sediments of mid-to-late Pleistocene age, which tend to be tilted in the vicinity of the surface rupture, and (2) dark brown, relatively coarse-grained, nearly horizontal Holocene sediments (Table 1, Figs. 3-7). The exact absolute time interval between these two deposits is unknown; however, there is unconformity, and the MRE mostly cut Holocene sediments (<10,000 years). A depositional gap, such as an unconformity, causes earthquake records to be missed during that time, leading to a misestimation of the slip rate. For this reason, in strike-slip fault settings, 3D trenching should be used because the slip rate using displacement from 2D trenches is underestimated compared to the slip rate using topography, which preserves most of the displacement. The slip rates in this study (0.12-0.14 mm/yr) are lower compared to the slip rates derived from the topography and 3D-trench reported in the study area of 0.38-0.57, 0.5 mm/yr, respectively (Kim et al., 2024; Naik et al., 2024). Nevertheless, the slip rates in our study are meaningful as a minimum value that establishes a lower boundary for the slip rates in the study area.” |
| 503: drilling core<br>- drilled borehole (Trench 2) | |
| 505: but is likely to be an underestimate<br>- why? | |
| 506: minimum overall slip<br>- long-term | |
| 506: 0.02 mm/yr<br>- how did you get this value ?? | |
| 506: 0.38 mm/yr<br>- meaningless | |
| 506: and average was 0.14 mm/yr<br>- This value is too strange and meaningless. | |
| 507: 0.04-0.11 mm/yr<br>- how did you get this value? | |
| 513-516: the recent Holocene due to changes in the surrounding tectonic setting, such as changes in the thickness of the subducting plates and increases or decreases in far-field stress, but also due to local factors such as seasonal climate, fluid inflow, and increased stress accumulation on faults. Second, the discontinuous distribution of Quaternary sediments may have led to an overestimation of the slip rate using the MRE | |

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| - It is over-interpretation made using uncertain values derived from uncertain logic. | |
| 520-521: The unconformity in deposition is likely to have missed the earthquakes between the two periods and the MRE cut through younger sediments (Sadler effect; Sadler, 1999), causing the maximum slip rate to be overestimated.<br>- I'm not sure what you're trying to say. What does a depositional gap have to do with the overestimation of the maximum slip rate? | |
| 516: light<br>- (1) light | We modified the sentence.<br>***Line 508-509***<br>“sediments in the trench wall: (1) light brown, relatively coarse-grained sediments of mid-to-late Pleistocene age, which tend to be tilted” |
| 517: were observed<br>- tend | |
| 518: dark<br>- (2) dark | |
| 527: paleoseismological<br>- paleoseismic | We modified the sentence.<br>***Line 527***<br>“in Korean paleoseismic studies” |
| 529-534: Determining the recurrence interval and earthquake periodicity model of the intraplate is difficult. Earthquakes occur in a regular pattern along the boundary in an interplate; however, in an intraplate, they often occur randomly, depending on the heterogeneous and complex interior structure (Liu and Stein, 2016). Long recurrence intervals of 400 ka have been reported for intraplate (Williams et al., 2017);<br>- repeated; It's unnecessary | We removed the sentence. |
| 534-535: over 10,000 years<br>- This value is based on the ca. 9.5 ka above-mentioned? The authors need to describe this value by comparing it directly with the MRE, PE, and AE obtained from the trench surveys. | We modified the sentence.<br>***Line 523-526***<br>“The recurrence interval between MRE and PE is similar to the minimum value of the time gap shown in Figure 9 and the value estimated by the slip rate. Between PE and AE, the recurrence interval calculated from the slip rate is smaller than the time gap obtained in Figure 9. It suggests that the earthquake records in the trench are not complete. Therefore, we can make a conservative estimate that the recurrence interval of the study area is over 13,000 years” |
| 544: the hanging wall of the fault core, with no Middle Pleistocene sediments observed<br>- Please rewrite. I can't understand | We modified the sentence.<br>***Line 533-534***<br>“First, the hanging wall of the Quaternary slip surface is mostly deposited with Holocene sediments only, with no Middle Pleistocene sediments present.” |
| 545-548: Second, NNE to N-S striking slip surfaces with high-angle dips were present within the fault core, and slickenlines developed on these slip surfaces, indicating dextral strike-slip with rakes of 10° or less. The main fault surface, which cut Quaternary sediments, dictated E-W compression; however, most shear fractures and slip surfaces in the fault core indicated NE-SW compression<br>- It is unclear whether the characteristics of the | We modified the sentence.<br>***Line 535-536***<br>“Second, NNE to N-S striking Quaternary slip surfaces with high-angle dip have rakes of 20˚ or less, indicating dextral slip with a minor reverse component.” |

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| bedrock faults or the Quaternary faults. Please clarify the distinction for the readers.<br>Attributing too much significance to the kinematics of the bedrock faults here can only lead to confusion among the readers. | |
| 566-568: The NE-SW compression shown by the slip surfaces and shear fractures within the pre-existing fault core is also consistent with a stress field that generates dextral strike-slip movement, which is the major deformation of the Yangsan Fault (Cheon et al., 2017, 2019)<br>- Is this sentence meaningful in the context of the logic in this section? | We removed the sentence. |
| 571-575: Given that the present-day ENE-WSW stress field acting on the Korean Peninsula has existed since 5 Ma (Kim et al., 2016), it is reasonable to infer that the study area has been continuously faulted with the same kinematics since the beginning of the Quaternary. The hanging wall of the main fault surface that cuts the Quaternary sediments is composed of a pre-existing fault core not only in the study area but also in other Quaternary fault sites along the Yangsan Fault. In all reported Quaternary fault sites<br>- The authors could also simplify this entire paragraph significantly. This part just shows how the results presented in previous literatures about the Yangsan Fault's Quaternary faulting patterns align with the findings of this study. Additionally, any geographical names mentioned in the text must be presented in the figures. | We modified the sentence<br>***Line 549-562***<br>"A Quaternary surface rupture with a top to the west geometry and its hanging wall composed of fault core is characterized not only in the study area but also throughout the Yangsan Fault. All Quaternary fault sites on the Yangsan Fault, except for the Bogyeongsa site (top-to-the-east, BGS in Fig. 10; Lee et al., 2022), show the top-to-the-west geometry of the main surface rupture (Kyung, 2003; Choi et al., 2012; Cheon et al., 2020a; Han et al., 2021; Ko et al., 2022; Lim et al., 2022; Kim et al., 2023). At the Quaternary fault sites north of the study area, pre-existing fault cores are observed on the hanging wall of the main slip surface (Kyung, 2003; Choi et al., 2012; Han et al., 2021; Lee et al., 2022; Ko et al., 2022; Lee, 2023). In the southern part of the study area, the pre-existing fault core constitutes a hanging wall up to Miho (MH in Fig. 10) and Inbo-N site (IBN in Fig. 10), located in southern Yangsan Fault (Kim et al., 2023). However, the Quaternary fault sites south of Inbo-N site show different deformation patterns from those to the north. In the Inbo site (IB in Fig.10), which is closest to the IBN trench, surface rupture developed between unconsolidated sediments (Cheon et al., 2020a), these features are also present in other fault sites of the southern Yangsan Fault (Choi et al., 2012; Lim et al., 2022). The deformation pattern of the Quaternary faulting of the northern Yangsan Fault is top to the west, with the main fault core and unconsolidated sedimentary layers abutting the main surface rupture, while the Quaternary faulting of the southern Yangsan Fault is characterized by the development of the surface rupturing between unconsolidated sedimentary layers." |
| 580: Mihori<br>- Miho site | |
| 581: Ulju-gun<br>-delete | |
| 581: MH<br>- Miho, Inbo-N sites | |
| 582: trench (IB)<br>- site | |
| 587-593: The Mihori area, which has been suggested as the boundary between the central and southern Yangsan faults (Choi et al., 2017), is a point location where the trend of the Yangsan Fault changes on the surface. The fault-line valley was relatively wide south of Mihori and narrowed as it passed through the Mihori area. In addition, the distribution of aftershocks was concentrated in | We removed this confusing part. |

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| this area during the 2016 Gyeongju earthquake and the geometry of surface geological surveys and faults suggests that this area is prone to deformation (Kim et al., 2017). Taken together, the topographic, structural, seismic, and paleoseismic features of the Mihori area suggest a high probability of large earthquakes or future earthquakes.<br>- I completely disagree with this part. The boundary between the Southern Yangsan Fault and the Northern Yangsan Fault is Gyeongju City, and the Wolsan site is located near this boundary. It is not convincing why significant importance is attributed to the Miho site (Kim et al. 2023).<br>The authors did not study this area yourself and are limiting your discussion to previous literature. This part does not need to be discussed in this study. Delete! | |

| Comment | Change made |
| --- | --- |
| ***Reviewer 2*** | |
| ***Major comments*** | |
| Based on the current quality of this manuscript entitled “Quaternary surface ruptures of the inherited mature Yangsan fault: implications for intraplate earthquakes in Southeastern Korea”, it is unsuitable to accept this current manuscript; a thorough revision should be made. Thus, I recommend a major revision before publication. The general comments are as follows: | Thank you for your time and effort in offering us constructive feedback. We did our best to digest and incorporate the valuable comments. We are sure that the current manuscript has been greatly improved to meet the journal's standards and quality. |
| The northern segment of the Yangsan fault is a right-lateral strike-slip fault. If there are any associated offset channels, terraces, or alluvial fans, the authors should provide some figures to show these offset landforms.<br><br>The authors should add a tectonic geomorphic map for each trench site, showing the offset landforms, sedimentary environment, etc., to give readers more comprehensive information about the trench location. | Thanks. We found several geomorphic offsets along the fault trace, so we added geomorphic information in chapter 2.2, 3.1, 4.1, and Appendix A.<br><br>***Line 113-120***<br>**2.2 Geological settings of the Byeokgye section of the Yangsan Fault**<br>The Northern Yangsan Fault, located north of Gyeongju at the junction of, the Ulsan and Yangsan Faults, has documented several Quaternary surface ruptures (Fig. 1b). These surface ruptures caused offsets in alluvial fans, river terraces, and deflected rivers with dextral displacements of 0.43-2.82 km (Kyung, 2003; Choi et al., 2012; Lee et al., 2019; Han et al., 2021; Ko et al., 2022; Lee et al., 2022; Lee, 2023). Recent significant earthquakes in Pohang and Gyeongju further underscore the seismic activity of this region. The Byeokgye section, which crosses Gyeongju and Pohang, is located in the southern part of the Northern Yangsan Fault, adjacent to the Yugye and Bangok sites to the north. In contrast, no Quaternary surface rupture has been identified in the Angang area to the south.<br><br>***Line 152***<br>**3.1 Fault surface rupture tracking and trench siting**<br>The detailed topography of the study area is described in Appendix A.<br><br>***Line 255-259***<br>**4.1.1 Trench 1**<br>It is located on the main lineament, approximately 1 km north of the Byeokgye site (Fig. 2c), within a cultivated field where a narrow 50 m wide N-S trending valley and a 20 m wide NE-trending valley meet, through which the main lineament passes. To the east of Trench 1, a NE-trending ridge develops, although this is currently difficult to identify due to human modification, while to the west, a hill with a N-S trending ridge is formed (Fig. A2). Fault scarps are distinctly visible along the main lineament, both to the south and north of Trench 1, with small fluvial and colluvial deposits observed on the surface.<br><br>***Line 316-320***<br>**4.1.2 Trench 2**<br>Trench 2 is located on the main lineament 0.8 km north of Trench 1 (Fig. 2c), within a colluvial area where fault scarp extend continuously along the main lineament to the south and north. Just north of Trench 2, the transition to an alluvial fan is clearly visible where the mountain ridge meets the main lineament. The 25-m wide valley surface contains partially developed colluvial sediments and deposits from small streams and gullies.<br><br>***Line 357-361***<br>**4.1.3 Trench 3**<br>Trench 3 is located on the main lineament extending 1.7 km north of the Trench 2 (Fig. 2c), within a cultivated field next to a wide road at the mouth of a broad basin. Fault scarps along the main lineament extend both south and north of the Trench 3. This trench marks the northernmost |

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| | point where the transition to the alluvial fan is observed where the mountain ridge meets the main lineament; beyond this point, fault scarps continue to develop on the alluvial fan surface.<br><br>***Line 388-392***<br>**4.1.4 Trench 4**<br>Trench 4 is situated on a NE-striking eastern branch lineament from the main lineament, which stretches 2.8 km north of the Trench 3 (Fig. 2c). South of Trench 4, a continuous dextrally deflected stream follows the branching lineament, with smaller displacements identified further north. Trench 4 lies at the edge of an alluvial fan near a hillslope, with two features separated by a stream.<br><br>***Line 415-417***<br>**4.1.5 Trench 5**<br>Trench 5 is located 40 m north of Trench 4. Because of its proximity, Trench 5 shares identical topographic characteristics with Trench 4, except that it lies on the margins of a hillslope instead of on an alluvial fan.<br><br>***Line 627-657***<br>**Appendix A. Geomorphic map of study area**<br>The topography of the study area in Ha et al. (2022) is summarized as follows:<br>The study area's topography is divided into a lowland area to the west and a mountainous region to the east (Fig. A1). The eastern mountains, the ridges extending from the summit are cut off by a lineament heading west, which influences the drainage system, with streams flowing from the high elevations east to the west. Alluvial fans, formed from sediments from the eastern mountains, are found at the base of the slopes. Twelve lineaments are identified, with the main lineament, which extends for 7.6 km, displaying high activity through the northern part of the Byeokgye site. Subsidiary high-activity lineaments and low-activity lineaments, mainly following N–S or NNE directions, are present, though many are valleys formed by erosion rather than rupturing. The main lineament exhibits continuous fault scarps and deflected streams, with reservoirs often located along it due to impermeable fault gouges that enable water storage. Topographic analysis revealed fault scarps, knickpoints, and displacement features along the main lineament, particularly visible in LiDAR data. Fault scarps are continuously and distinctly visible in the main lineament of the southern region (Fig. A2). In the cross-section, the fault scarps are recognized as knickpoints, and on the topographical map, the ridges on the east side of the lineament are cut by the surface rupture and merged with the alluvial fans. The main lineament of the northern region is identified as a linear arrangement of deflected streams and fault scarps (Fig. A3). Unlike in the south, the fault scarps in the north show surface uplift estimated at a vertical offset of between 2–4.2 m of the same alluvial fan surface cross-section. Differences between the southern and northern regions are observed, with the north showing vertical offsets of 2–4.2 m and more pronounced faulting. The horizontal offsets calculated based on the three deflected streams are 92 m, 98 m, and 150 m. The tendency for the offset to decrease as the distance from the main lineament increases indicates that the fault offset branching from the main surface rupture gradually decreases. |

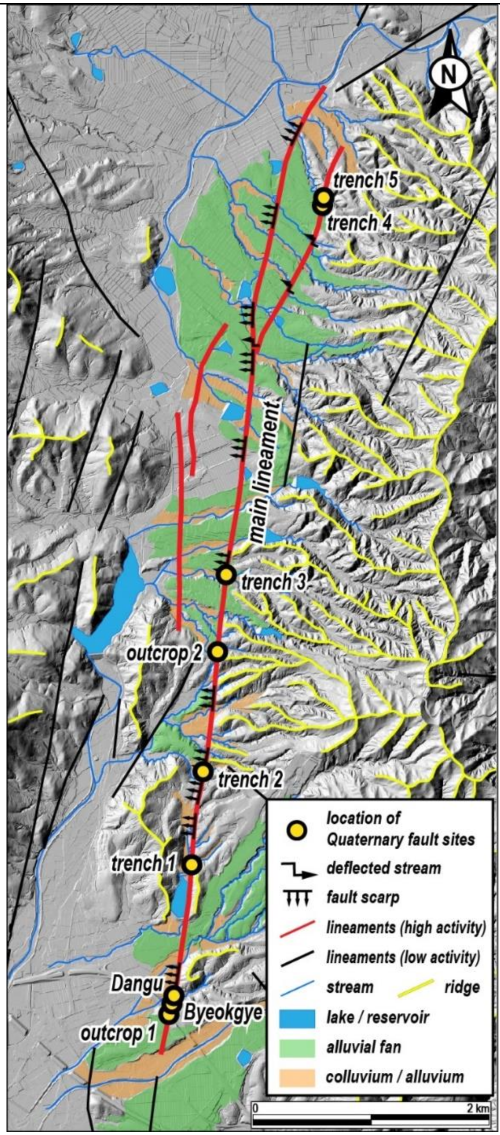


Figure A1: The geomorphic map of the study area (modified from Ha et al., 2022).

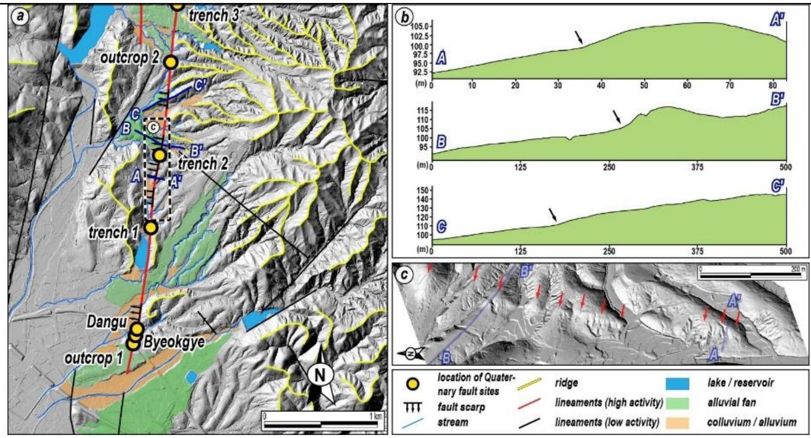


Figure A2: (a) A detailed topographic map of the southern region. (b) Topographic profiles along the main lineament (blue line in (a)) crossing the fault scarps. Black arrows mark knickpoints identified as fault scarps. (c) A 3D hillshade image. The red arrows highlight the fault scarp, which is clearly visible to the unaided eye.

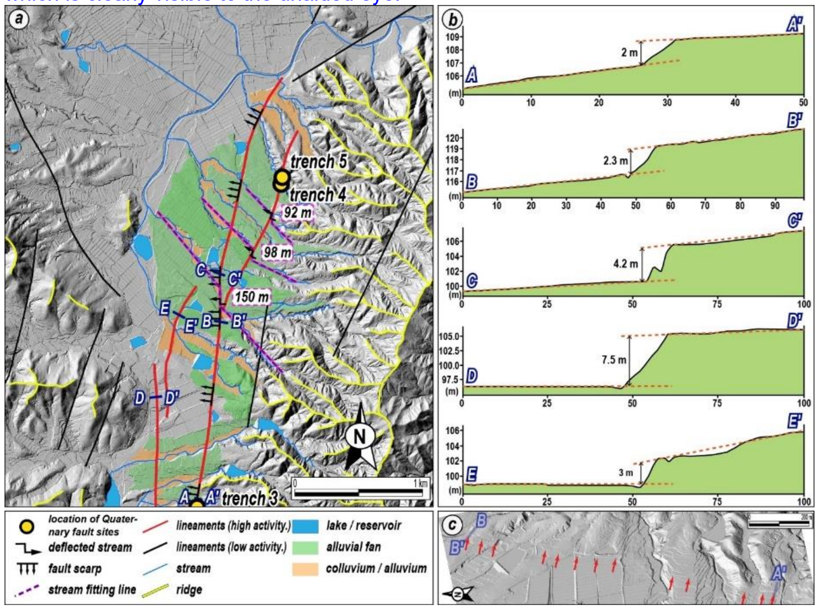


Figure A3: (a) A detailed topographic map of the northern region. An NNE lineament branching off from the main lineament is shown by the dextrally deflected stream. (b) Topographic profiles along the line (blue line in (a)) crossing the fault scarps. Fault scarps in the northern region are evident due to the elevation difference in the alluvial fan surfaces. (c) A 3D hillshade image. Red arrows highlight the fault scarp.

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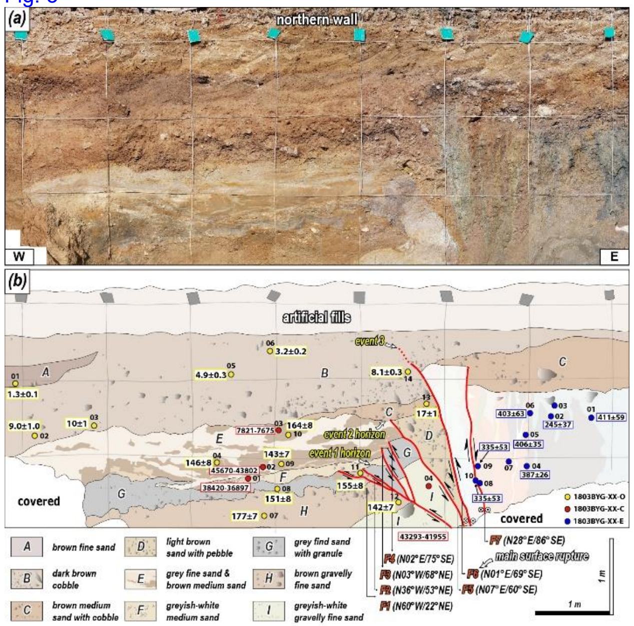
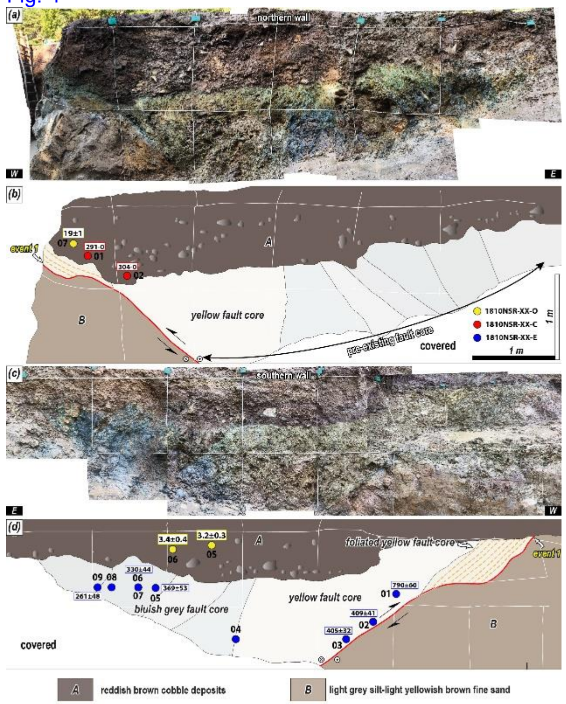
| It is suggested that the sample number should be marked on the trench logs to help readers judge the sample location. | Thanks, we added the sample number and each dating result in the trench logs.<br>Fig. 3<br><br><br>Fig. 5<br>Fig. 4<br><br><br>Fig. 6 |

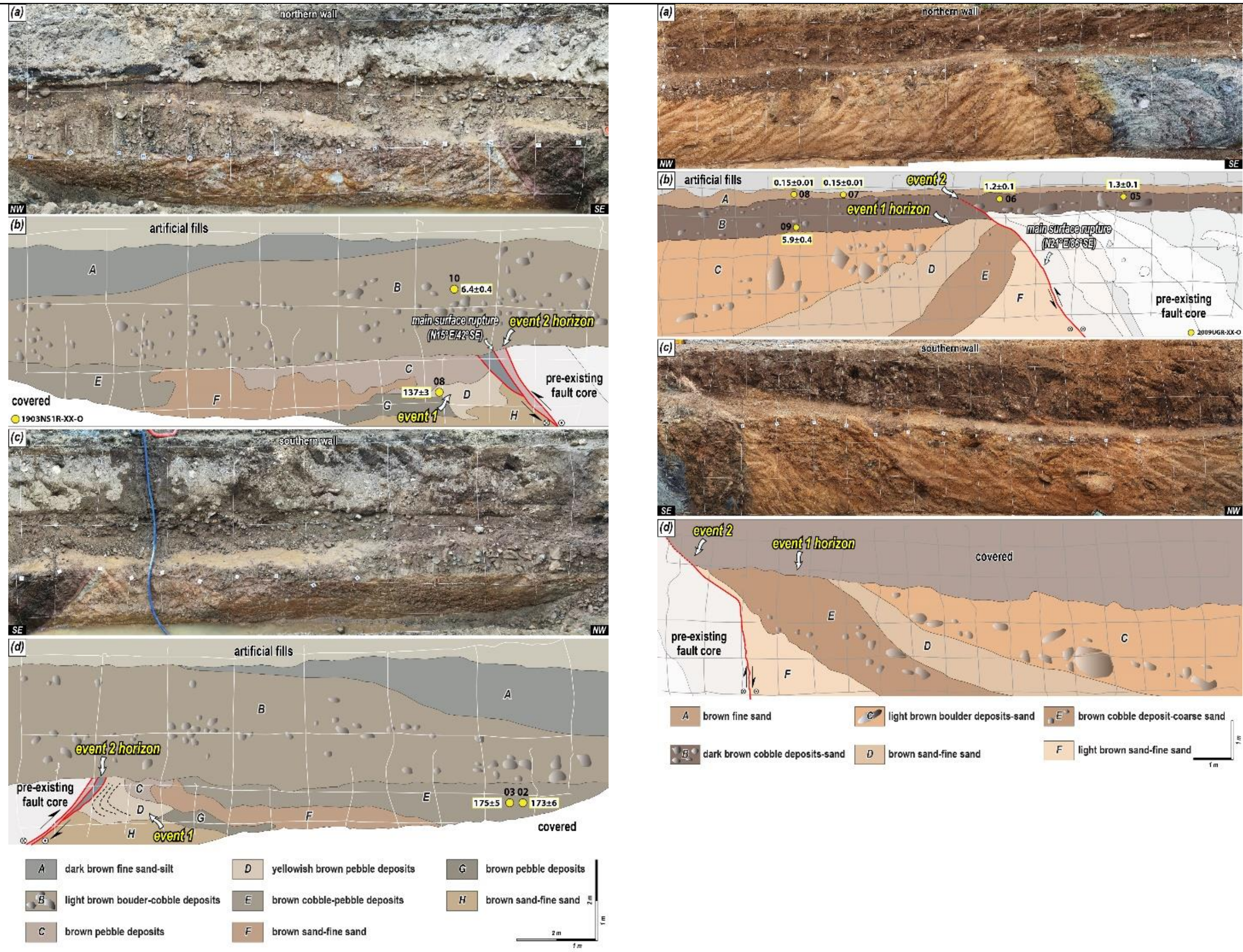

(a)
northern wall
NW
SE
(b)
artificial fills
A
B
10
6.4±0.4
main surface rupture
(N15°E/42°SE)
event 2 horizon
C
08
137±3
D
pre-existing
fault core
E
F
G
event 1
H
covered
1903NS1R-XX-O
(c)
southern wall
SE
NW
(d)
artificial fills
B
A
event 2 horizon
pre-existing
fault core
C
D
G
H
event 1
E
F
03 02
175±5
173±6
covered
A dark brown fine sand-silt
B light brown bouder-cobble deposits
C brown pebble deposits
D yellowish brown pebble deposits
E brown cobble-pebble deposits
F brown sand-fine sand
G brown pebble deposits
H brown sand-fine sand
2 m
1 m
(a)
northern wall
NW
SE
(b)
artificial fills
0.15±0.01
08
0.15±0.01
07
event 2
1.2±0.1
06
1.3±0.1
05
A
event 1 horizon
B
09
5.9±0.4
main surface rupture
(N21°E/68°SE)
C
D
E
F
pre-existing
fault core
2009UGR-XX-O
(c)
southern wall
SE
NW
(d)
event 2
event 1 horizon
covered
E
D
C
pre-existing
fault core
F
A brown fine sand
B dark brown cobble deposits-sand
C light brown boulder deposits-sand
D brown sand-fine sand
E brown cobble deposit-coarse sand
F light brown sand-fine sand
1 m

Fig. 7

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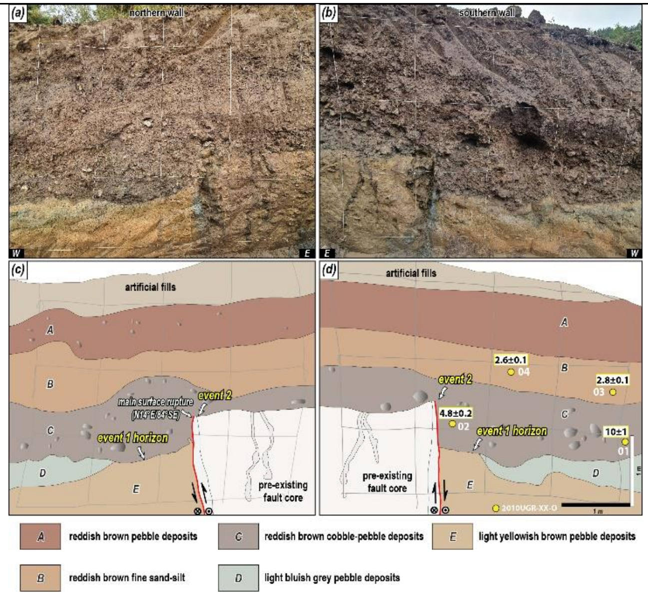
| |  |
| It is recommended to provide locally enlarged photos of the sampled strata to distinguish the characteristics of the sedimentary strata. Because the reliability of OSL dating results is related to the sedimentary characteristics. Based on the photos currently presented, the sorting and rhythmicity of the strata are both poor, which is unsuitable for OSL dating. | Thanks for the constructive comment.<br><br>We understand what the reviewer tried to mean, but the reliability of luminescence dating results may not be necessarily related to depositional environments (or processes). As the reviewer may know, there have been lots of published papers where luminescence dating results were used as useful age controls for age-unknown sediments that had formed in various environments (e.g., glaciofluvial, alluvial fan, marine, and what not).<br><br>Having said that, we are well aware that the physical characteristics of luminescence signals (quartz OSL signal, in particular) can be controlled by sedimentation processes. For instance, in general, as the transportation distance of mineral grains increases, the luminescence signal properties become more suitable for reliable age estimation; It is well known that the fast quartz OSL signal, which is the main target signal for quartz OSL dating, become prominent with the increase in transportation distance. Besides, it is also true that the well-sorted sediments, which are presumed to be of uniform natural radioactivity, put much less complexity in environmental dose rate estimation than poorly sorted ones.<br><br>As represented in Appendix D, the quartz OSL signals for all the samples appear to be dominated by the fast OSL signal component. Further, both quartz OSL and K-feldspar $pIRIR_{225}$ signals passed through the acceptance criteria of the SAR protocol (e.g., recycling ratio within 10% of unity, recuperation less than 5 % of the natural signal intensity etc.). As depicted with probability density plots showing negligible skewness (Figure E1), we could not detect any clear evidence of detrimental effects from substantial incomplete bleaching of luminescence signals at deposition, although the luminescence signal measurements were performed using multiple grain single aliquots (“3 mm” aliquots). From the perspective of dose rate estimation, most samples were collected from homogeneous sandy layers, at least ~ 30 cm away from pebble clasts. Where it was unavoidable to take samples from pebbly sediments, we separately collected representative sediment samples, mixture of sands and pebbles, and pulverized them for homogenization. Then these were used for gamma measurements (environmental dose rate estimation). Therefore, we consider that the presence of pebble clasts, together with sandy grains, did not give rise to substantial luminescence age bias. Based on these, there is no reason to doubt the reliability of the luminescence ages of the samples, particularly with regard to the degree of sorting, and we conclude that the luminescence ages presented here can be given credence, at least at this stage of investigation. |

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| There is significant uncertainty in the calculation method of slip rate in the text, which is also pointed out by the author. The best way to limit the slip rate of strike-slip faults is to use the displaced geomorphic surface to constrain the slip rate. It is suggested that the author can do such work in this area in the future. | That's a great comment.<br>To best address your comment, we have replaced true displacement with horizontal displacement, presented slip rate and displacement based on horizontal as well, and clearly stated the uncertainties and limitations associated with this in strike-slip faulting settings.<br><br>***Line 224-250***<br>**3.4 Displacement and earthquake magnitude estimation**<br>The slickenlines of the main surface rupture and the vertical separation of the Quaternary sediments in the trench wall are used to determine the horizontal displacement of the MRE and the displacement per event. In general, for strike-slip faults like the study area, horizontal displacements must be obtained from 3D trenches or from topography that preserves the displacements almost intact (e.g., Kim et al., 2024; Naik et al., 2024). Using only 2D trenches to obtain displacements or slip rates is uncertain because the sedimentary layers are unlikely to have recorded all earthquakes. Furthermore, deriving the horizontal displacement is challenging when exposed walls are inclined, markers are inclined, or the slip sense is not purely dip-slip or strike-slip (which is almost always the case). In addition, displacements based on fragmentary information, such as bedrock separation and thickness of Quaternary sediments, can be over- or underestimated by fault slip motion and the possibility of paleo-topographic relief cannot be ignored. Despite these uncertainties, fault displacement is a necessary factor in earthquake magnitude estimation and key paleoseismological information, and the displacement obtained from the 2D trench can be used as a minimum value; therefore, the process of collecting or estimating fault displacement is indispensable in paleoseismology. Therefore, correlations based on vertical separation, marker dip angle, angle of slope wall, fault dip angle, rake of slickenline, etc. are important for estimating the horizontal displacement of a fault (Fig. B1; Xu et al., 2009; Jin et al., 2013; Lee et al., 2017; Gwon et al., 2021). The method of using their relationship to find the horizontal displacement is described in detail in Appendix B.<br>Variables used for earthquake magnitude estimation include average displacement (Kanamori, 1977), maximum displacement (MD; Bonilla et al., 1984; Wells and Coppersmith, 1994), surface rupture length (Bonilla et al., 1984; Khromovskikh, 1989; Wells and Coppersmith, 1994), rupture area (Wells and Coppersmith, 1994), and surface rupture length × MD (Bonilla et al., 1984; Mason, 1996). However, in Korea, where rupture traces are difficult to find, it is difficult to use surface rupture length or rupture area owing to large uncertainties. Thus, we used MD (horizontal displacement), which is relatively easy to obtain from outcrops and trenches and more reliable. Many previous studies within intraplate have applied the empirical relationship of the MD-moment magnitude ($M_w$) presented by Wells and Coppersmith (1994) (e.g., Patyniak et al., 2017 in Kyrgyzstan; Suzuki et al., 2020 in Mongolia; Je et al., 2024., in China). We also estimated the maximum earthquake magnitude by applying the MD obtained from the trench to the empirical formula. The rake of slickenlines on the Quaternary slip surface that underwent faulting averages 20° and strike-slip motion is dominant; therefore, we used a corresponding strike-slip fault type $M_w$-MD empirical relationship.<br><br>***Line 450-468***<br>**4.4 Displacement and earthquake magnitude estimation**<br>The results calculated using the marker, vertical separation of each trench, and Eq. (B1) are listed in Table 5. In the previous study by Lee et al. (2016), the horizontal displacement of the MRE at the Dangu site is determined to be 2.55 m. For each surface rupturing event in Trench 1, the horizontal displacement per event according to the event horizon is 0.9–1.05 m, and the horizontal displacement of the MRE is 1.72 m. Using the bedrock and Quaternary sediments unconformity identified by corings in Trench 2 as a marker, the cumulative horizontal displacement is 76 m. The MRE cutting the colluvial wedge in Trench 3 has a horizontal displacement of 2.85 m. However, when considering the overall interpretation, only the MRE and AE, but not the PE, are recognized in Trench 3 (Figs. 5 and 9). The displacement cutting the colluvial wedge likely reflects the displacement of the missing PE as well as the MRE, which is supported by the long interval between the wedge (unit D) and the deposit covering the wedge (unit B). Thus, it is reasonable to exclude the calculated displacement as it is unlikely to be the displacement of the MRE. The horizontal displacement of the MRE in Trench 4 and 5 are 0.82 m and 2.21 m, respectively, using the lower boundary of units B and C as markers. Combining the results from each trench, the horizontal displacement of MRE in the study area is 0.82–2.55 m and the cumulative horizontal displacement is 76 m. The horizontal displacement per event is similar, between 0.9–1.05 m for PE and AE (event 1, 2), but the trench shows a higher displacement for the MRE (event 3).<br>We estimated the maximum earthquake magnitude by applying the MD (horizontal displacement: 0.82-2.55 m) of the MRE, resulting in a maximum magnitude estimate 6.7–7.1. Seismic SSDs such as the 20-50 clastic dike and 30 cm ball-and-pillow structure observed in the exposed wall (units E and G in Trench 1; unit F in Trench 3), serve as indirect evidence indicating an earthquake of at least magnitude 5.5 (Atkinson et al., 1984). |

**Table 5. Fault displacement of study area**

| | | $S_v$ (m) | α (˚) | γ (˚) | $S_t$ (m) | **$S_h$ (m)** |
|---|---|---|---|---|---|---|
| Dangu[a] | MRE (event 3) | 0.67 | 79 | 15 | 2.64 | **2.55** |
| | Marker | Unit D | | | | |
| Trench 1[b] | MRE (event 3) | 0.49 | 69 | 17 | 1.8 | **1.72** |
| | Marker | Unit C | | | | |
| | PE (event 2) | 0.31 | 75 | 17 | 1.1 | **1.05** |
| | Marker | Unit G | | | | |
| | AE (event 1) | 0.22 | 53 | 17 | 0.94 | **0.9** |
| | Marker | Unit H | | | | |
| Trench 2 | Cumulative displacement | 34 | 38 | 36 | 94 | **76** |
| | Marker | Quaternary deposits thickness | | | | |
| Trench 3 | MRE (event 3) | 1.1 | 42 | 30 | 3.29 | **2.85** |
| | Marker | Unit D | | | | |
| Trench 4 | MRE (event 3) | 0.25 | 86 | 17 | 0.86 | **0.82** |
| | Marker | Unit B | | | | |
| Trench 5 | MRE (event 3) | 0.8 | 84 | 20 | 2.35 | **2.21** |
| | Marker | Unit C | | | | |

***Line 493-518***

**5.1.2 Quaternary slip rate and recurrence interval**

The slip rate is an expression of the average displacement of a fault over a certain period, which numerically shows how quickly energy (stress) accumulates in a fault zone and is used as an important input parameter in seismic hazard assessment (Liu et al., 2021). The horizontal slip rate in the study area is calculated based on the earthquake timing and horizontal displacement of each trench. We calculated slip rates from three trenches spanning different periods: Late Pleistocene to Holocene (Trench 1), Quaternary (Trench 2), and Middle Pleistocene to Holocene (Trench 3). In Trench 1, we derived a slip rate of 0.12-0.14 mm/yr based on the horizontal displacement of event 3 (MRE) of 1.72 m and the 13.8±1.2 ka time interval between events 3 and 2 (time gap between units B and C; Table 1). For Trench 2, borehole data revealed a slip rate of 0.02-0.03 mm/yr, calculated from the cumulative horizontal displacement of 76 m and the cosmogenic $^{10}Be$-$^{26}Al$ isochron burial age of 2.87±0.59 Ma from the lowermost Quaternary deposits. In Trench 3, we calculated a slip rate of 0.02 mm/yr using the 2.85 m horizontal displacement of the event that cut the colluvial wedge (unit D) and the 130.6±3.4 ka time interval between events (time gap between units B and D).

Considering the age of the deposits, the slip rate of 0.12-0.14 mm/yr from Trench 1 represents movement during the Holocene, while the rates from Trenches 2 and 3 may represent cumulative slip rate (0.02 mm/yr) throughout the Quaternary. As noted in the method section (3.3), there are uncertainties in obtaining slip rates from 2D trenches alone on strike-slip faults such as the study area. In particular, the discontinuous distribution of Quaternary sediments may have led to a misestimation of the slip rate. There are two distinct types of sediments in the trench wall: (1) light brown, relatively coarse-grained sediments of mid-to-late Pleistocene age, which tend to be tilted in the vicinity of the surface rupture, and (2) dark brown, relatively coarse-grained, nearly horizontal Holocene sediments (Table 1, Figs. 3-7). The exact absolute time interval between these two deposits is unknown; however, there is unconformity, and the MRE mostly cut Holocene sediments (<10,000 years). A depositional gap, such as an unconformity, causes earthquake records to be missed during that time, leading to a misestimation of the slip rate. For this reason, in strike-slip fault settings, 3D trenching should be used because the slip rate using displacement from 2D trenches is underestimated compared to the slip rate using topography, which preserves most of the displacement. The slip rates in this study (0.12-0.14 mm/yr) are lower compared to the slip rates derived from the topography and 3D-trench reported in the study area of 0.38-0.57, 0.5 mm/yr, respectively (Kim et al., 2024; Naik et al., 2024). Nevertheless, the slip rates in our study are meaningful as a minimum value that establishes a lower boundary for the slip rates in the study area.

***Line 659-672***

**Appendix B. Calculation of horizontal displacement**

The horizontal displacement ($S_h$) can be calculated using a trigonometric function that considers the vertical displacement ($S_v$), fault dip angle ($\alpha$), rake ($\gamma$), true displacement ($S_t$) and their relationships (Fig. B1; Eq. B1). Assume that the attitude of the marker in the exposed wall at each trench is nearly horizontal in three dimensions and the angle ($\beta$) of the exposed wall is nearly vertical, then the two factors are perfectly horizontal and vertical, respectively. Thus, the vertical separation ($S_{vm}$) and vertical displacement ($S_v$) measured in the exposed wall are equal. Therefore,

$$\boldsymbol{S_{vm} = S_v, S_m = \frac{S_v}{\sin\alpha}, S_t = \frac{S_m}{\sin\gamma}, S_h = \cos\gamma * S_t} \quad \text{(B1)}$$

We calculate horizontal displacement ($S_{h)}$ using Eq. (B1) for vertical separation ($S_{vm)}$ of the marker measured in the exposed wall, as shown in Table 5.

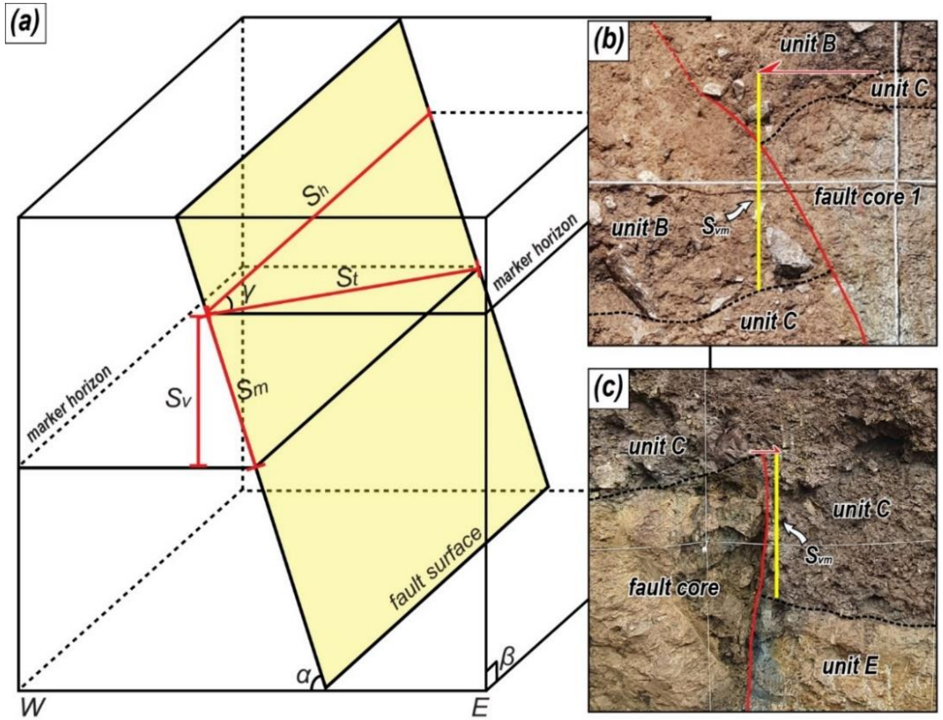


Figure B1: (a) Schematic diagram showing how to calculate true displacement. $S_h$: horizontal displacement $S_t$: true displacement, $S_v$: vertical displacement, $S_m$: dip separation, α: dip of fault surface, β: dip of cut slope, γ: rake of the striation (modified from Xu et al., 2009). (b and c) Photographs showing the measured vertical separation of the trenches 1 and 5. $S_{vm}$: vertical separation.

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| I fully agree that the Yangsan fault is a Holocene active fault from the dating results. Overall, the trenches were not as effective as expected, with problems such as discontinuous deposition and less carbon-14 dating material. I suggest the authors carry out more detailed work and select a more suitable geomorphological location to excavate the paleoseismic trench in the future, providing the recurrence interval of the strong earthquakes. | Great suggestion.<br><br>We are on the same boat with the reviewer on this matter. So, we have already added the limitations of our study to the conclusions. However, there exist much limitation in paleoseismic research in Korea. Rapid erosion rates and low deposition rates due to the humid climate, coupled with low tectonic activity relative to plate boundaries, make it difficult to recognize surface ruptures even if they occurred. Numerous cultivated fields and much human disturbance make trench site selection more difficult. It is also very difficult to obtain radiocarbon targets, and even if you can, there is a lot of room for misinterpretation due to tree root penetration in dense forests. So far, only one paleoseismic study in Korea has yielded a reliable radiocarbon age. In other words, Korea is the antithesis of arid regions with well-preserved surface rupture and regions of high tectonic activity. Given together, we believe that these difficulties make our research more valuable. Thank you again for your constructive comments. |