Form V

United Nations Educational, Scientific and Cultural Organization

Report year: **2017**

Annual Report* of IGCP Project No. 641

***NOTE: MAXIMUM LENGTH OF THE TEXT REPORT IS 5 (FIVE) PAGES (starting from question 1). SINGLE SPACE, 12 POINT FONT. REPORTS EXCEEDING THIS LENGTH WILL BE RETURNED TO THE AUTHOR(S) WITH THE REQUEST OF REDUCING THE TEXT TO THE ABOVE STANDARD.**

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by 01/12/2017

A LIST OF PUBLICATIONS HAS TO BE ADDED AS AN ANNEX.

***REMINDER: IF THIS IS THE FINAL YEAR OF YOUR PROJECT, PLEASE SUBMIT A REVIEW ARTICLE ABOUT YOUR PROJECT TO THE IUGS JOURNAL '*EPISODES*'.**

The scientific information in this report will further be used for publication on the IGCP website hosted at UNESCO (please feel free to attach any additional information you may consider relevant to the assessment of your project).

IGCP project short title: Deformation and fissuring caused by exploitation of subsurface fluids (M3EF3)

Duration: 4 years

Please tick this box if the report is for a Project on extended term (OET): ☐

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Date of submission of report: 1st December, 2017

Signature of project leader(s):

Dora Carreon-Freyre

Devin Galloway

Pietro Teatini

Shujun Ye

1. Website address(es) related to the project

The main website http://www.igcp641.org/, is updated continuously with the input of participants, and in particular a call for input was made at the 3rd IGCP-641 workshop (2017) for the improvement of the database of the 'ground fracturing' world map. A workshop webpage (https://web.ua.es/es/m3ef3/news.html) was developed for the 3rd workshop in Alicante, Spain.

2. Summary of major past achievements of the project

Detailed information is presented in ***Annex No. 1***

- An international network of about 50 researchers from 12 countries established;
- A M3EF3 project web-page has been developed within ResearchGate (https://www.researchgate.net/project/Mechanisms-Monitoring-and-Modeling-Earth-Fissure-generation-and-Fault-activation-due-to-subsurface-Fluid-exploitation-M3EF3) with about 30 participants;
- Annual M3EF3 workshop held in Puerto Vallarta, Mexico and a Special Session. RAUGM2017, 2–3 November 2016
- Update of the project website;
- Publications in international journals;
- Two sessions (NH014, H087) co-organized at AGU Fall Meeting 2016

3. Achievements of the project this year only

3.1. General scientific achievements

Scientific achievements in each of the 3 main topics of the project can be summarized as follows (detailed information is presented in ***Annex No. 1***):

- Mechanisms: The main 3-4 mechanisms responsible for ground rupture development in subsiding basins were defined. Appropriate new material was been added to the project website. A theoretical modelling study was begun and the ongoing study seeks to quantify the main drivers/conditions causing earth fissures and fractures development (preliminary results will be presented at the international conference MODSIM 2017).

- Monitoring: Specific in-situ and remote-sensing methodologies were developed, tested and established: fiber-optics horizontal extensometers were established in Wuxi (China); advanced FFT analyses of InSAR-based displacement maps and time series were applied to Mexico City; a novel 3D reconstruction of fissure geometries from drone acquisitions were developed in Spain and tested on specific study cases, ground-mapped fissures in Arizona. Furthermore. a first map of ground fractures was developed for Mexico City and a first world map of the ground ruptures occurrence has been released and published on the project website at http://www.igcp641.org/?page_id=45.

- Modelling: To understand the geomechanical processes caused by groundwater pumping in a sedimentary basin we developed an integrative analysis using 3D numerical models with an accurate geological framework. The heterogeneous distribution of the geomechanical properties and the differential deformation and stress field in a subsiding basin is a complex issue that has not been addressed in detail in the literature. A manuscript with these results was submitted recently (Ochoa et al., submitted). Specific 3D numerical models using Finite Elements and Interface Elements were developed and applied for two sites, Wuxi, China, and Queretaro, Mexico. A new methodology integrating regional and local models allows scientists (for the first time) to account for the development and motion on fissures as features in the propagation of deformation in sedimentary basins. A first example was published in the framework of the collaboration Italy-China (Ye et al., submitted).

3.2. List of IGCP project meetings/symposia and IGCP related meetings/symposia with exact attendance (if possible) and number of countries

Eight meeting/symposia were organized in different countries (USA, Australia, Spain, Holland, Mexico, China, Taiwan). A detail list is presented in ***Annex No. 1***.

The main activity of the project was the organization of the 3rd IGCP641 Annual Meeting. 16-17 November, 2017 in Alicante, Spain with 35 attendants from Spain, Mexico, USA, Italy, China, Japan, The Netherlands, Egypt, Pakistan, Poland, Taiwan, Colombia.

3.3. Educational, training or capacity building activities related to the IGCP project and IGCP project participants.

The project website has been deeply enlarged. General informative materials have been added. Reports and publications downloadable from the website have been added (part of them available to the IGCP participants only for copyright issue). A world map with about 45 sites affected by ground ruptures (and related metadata, i.e. subsidence rates, main mechanisms, scientific references) is accessible from the website. The educational activities developed specifically in Italy, China and Mexico are detailed in ***Annex No. 1***.

The ***Third Workshop of the IGCP 641 Project*** at the University of Alicante, Spain (https://web.ua.es/es/m3ef3/news.html) included the participation of MSc students from the University of Alicante (Engineering Department) and staff of the Geological Survey of Spain. Involvement of young researchers from developing countries, in particular from Pakistan and Iran which are two of the countries worldwide most affected by ground rupture hazard.

*3.4. List of countries involved in the project (please *indicate the countries active this year and make the distinction between:*

Active countries this year: China, Mexico, Italy, Spain, USA, Poland, Pakistan

Other countries: Canada, Australia, The Netherlands, Philippines, Colombia, UK, Germany, Iran

According with the collected (scientific) information, other countries where ground rupture is related to the geological structures are India, South Africa, Saudi Arabia. Our attempts on establishing new contacts are in progress.

3.5. Participation of scientists from developing countries.

	Total number of scientists	*Number of male scientists*	*Number of female scientists*
Number of participating scientists	65	50	15
Number of young scientists/students (<35 years old)	24	15	9
Number of scientists from developing countries	31	19	12

Work conducted from the University of Padua PhD students was essential to achieve our goals in term of modelling. The majority of the female participants are from developing countries. The above table shows only those participants registered on the webpage of the project. There are actually more people involved, especially many students from the universities and institutes. Taking the Nanjing University as an example, **there are 6 *young scientists/students (<35 years old) working on this project.*** *More information is presented in* ***Annex No. 1***.

3.6. List of the 5 most important publications (including maps) of this year

a) could not have been published were if not for this project

The first world map of sites affected by ground rupture has been published and freely available in the IGCP641 project website (http://www.igcp641.org/?page_id=45);

b) related to this project

- Galloway, D.L., and Leake, S.A., 2017, Regional land subsidence caused by the compaction of susceptible aquifer systems accompanying groundwater extraction: in Singh, V.P. (ed.),

Handbook of Applied Hydrology (2nd edn.), chpt. 56, McGraw-Hill Education, New York, p. 56.1–56.11.

- Map of ground fracturing in Mexico City. The map was included in the National Atlas of Risks (http://www.atlasnacionalderiesgos.gob.mx).Technical report, a publication is under preparation;
- S. Ye, A. Franceschini, Y. Zhang, C. Janna, X. Gong, J. Yu, and P. Teatini, A novel approach to model earth fissure caused by extensive aquifer exploitation and its application to the Wuxi case, China, Water Resources Research. Under review.
- G. H. Ochoa-Gonzalez, D. Careeon-Freyre, A. Franceschini, M. Cerca, and P. Teatini, Overexploitation of groundwater resources in the faulted basin of Queretaro, Mexico: a 3D deformation and stress analysis, Engineering Geology. Submitted.
- Hernandez Marin, M., Pacheco Martinez, J.., Burbey, T.J., Carreon-Freyre, D., Ochoa-Gonzalez, G, Campos-Moreno, G.., de Lira, P., Evaluation of subsurface infiltration and displacement in a subsidence-reactivated normal Fault in the Aguascalientes Valley, Mexico. Journal Environmental Earth Sciences. In press.

c) did you publish in Episodes during the project's duration or plan to do so? If not, why?

Yes. below detailed publication:

Teatini P., Carreon-Freyre D.. Ochoa-Gonzalez G, Ye S., Galloway D., Hernandez-Marin M., "Ground ruptures attributed to groundwater overexploitation damaging the Jocotepec city in Jalisco, Mexico: 2016 field excursion of IGCP-641" (Ms. N. E-17-13), was accepted in Episodes on August 24, 2017, and according to a last email from the journal managing editor, Bokyun Ko, dated November 5, 2017, the publication is scheduled in March issue, 2018.

We are planning to submit in the next year a second paper to Episodes focussed on the world map of ground rupture occurrences. The publications will be co-authored by the project leaders and all the more active M3EF3 participants.

3.7. Activities involving other IGCP projects, UNESCO programmes, IUGS Commissions or Task Groups or others. Complementary information is presented in ***Annex No. 1***.

- A "related" proposal for a new IGCP Project on "Impact, Mechanism, Monitoring of Land Subsidence in Coastal cities" with the leadership of China and Co-leader in Egypt, Indonesia, The Netherlands, and Italy.
- Support in the preparation of a proposal for the creation of a UNESCO Category 2 Center from the Key Laboratory of lands subsidence and earth fissures of Shanghai, China.
- The IHP-UNESCO Working Group on Land Subsidence is developing the study of earth fissures, ground fractures and reactivations of faults due to groundwater exploitation. A procedure to evolve to Land Subsidence International Initiative (LaSII) began in 2017. A first version of the proposal is presented in ***Annex No. 3***.

3.8. Scientific Legacy: Is there a need for storage of publications, field data, and other results of the project? Do you have a clear vision concerning where the data would be stored and who will be the custodian?

Yes, data are stored in the server of the Department of Civil, Environmental and Architectural Engineering, University of Padova, Italy. Pietro Teatini is the custodian and webmaster of the project.

3.9. What tangible improvements has your project obtained?

- The research has produced a few major scientific advances: a novel (and unique up to now) approach to model rupture development in real 3D geologic setting; an innovative methodology to detect ground ruptures by FFT processing of satellite SAR solutions; an original technique to process drone acquisitions for the volumetric characterization of ground ruptures and the fracture map of Mexico city indicated that the building damage caused by the 19th September earthquake 1985 was repeated during the 19th September 2017 earthquake.
- The number of research participants is increased to 65

(http://www.igcp641.org/?page_id=36). IGCP 641
Project leaders also supported the preparation of a proposal for the IGCP Project on Land Subsidence in Coastal Regions leaded by the Key Laboratory of Land Subsidence and Earth Fissures of Shanghai, China and co-leaded by experts from Italy, the Netherland, and Indonesia. More details about improvements are presented in ***Annex No. 1.***

3.10. What kinds of activities in respect to the benefit of society and science outreach has your project undertaken?
Dissemination of information to local authorities is of the most importance so as free access to the maps of fracturing. The National Disaster Prevention Center of Mexico (CENAPRED) integrated the map of fractures to the National Risk Atlas that can be free consulted and manipulated thanks to a GIS server. Several meetings have been carried out with key staff of a number of governmental agencies in China directly involved in managing ground rupture occurrence (Jiangsu Geological Survey, Shanghai Institute of Geological Survey, Beijing Institute of Hydrogeology and Engineering Geology, China Institute of Geo-Environment Monitoring). Projects are just started or are in the way of being finalized between these agencies and Chinese and abroad universities to develop detailed monitoring and modeling studies aimed at predicting ground fissures and reducing their hazard.
The leaders of the project had been Invited to give dissemination talks in different events, a detailed list is presented in ***Annex No. 1****.*

3.11. What kind of public information (media reports, etc.) has your project generated? And how do you evaluate their?
The map of fractures of Mexico City had a wide media cover during more than 3 weeks. It was a main heading subject of many TV interviews to Dora Carreon and newspapers notes. A part of them have been stored in the project website (http://www.igcp641.org/?page_id=1140). Some newspaper notes are presented in ***Annex No. 4****.*

3.12. Project highlight: Select one realization that happened during your project this year that you would like to see highlighted on the UNESCO-IGCP website (max. 400 words)
One of the main outcomes of the IGCP 641 M3EF3 is the realization of a world map with the location of the main occurrences of ground rupture. (Figure 1). Figure 1 and the detailed information about the Fracture Map are presented in ***Annex No. 1.***

4. Activities planned

4.1. General goals (detailed description are presented in ***Annex No.1****)*

- Establish collaboration with researchers from Iran, India, South Africa, Saudi Arabia;
- Update the Ground Rupture World Map;
- Foster enrolment of researchers in developing/newly-developed countries
- Possibly publish a book on IGCP641 issues and results.
- Continue with the numerical modelling applications;
- Organize a session on LS and ground ruptures at the AGU Fall Meeting 2018.

4.2. Tentative list of specific meetings and field trips (please list the participating countries)
Session NH021.Subsidence: Causes, Impacts, Mapping and Ground/Satellite Monitoring – 2017 AGU Fall Meeting – 11–15 December 2017, New Orleans, USA
May, 2018, Fourth Workshop of the IGCP 641 Project at the University of Arizona, USA or November, 2018 at the University of Nanjing, China.

5. Project funding requested

We request funding equal to $8000 to continue with our scheduled activities. We will use them, as this year, for flight tickets and accommodation, giving priority to young scientists and women for developing countries. Some funding will also be used for the organization of a field trip associated with our annual meeting.

6. Request for extension, on-extended-term-status, or intention to propose successor project

We would like to finish this phase during 2018 to continue the research work on modelling and better identify the mechanisms responsible for the generation of ground fractures. We are planning to prepare a second phase proposal focused on fractures and reactivation of faults related to groundwater exploitation, the application of M3 integrated approach to new sites and to improve the dissemination work (detailed description is presented in **Annex No. 1**)

7. Financial statement ($ USD only)

The IGCP Scientific Board would like to be informed how the IGCP funds were used.

Of the allocated resources provided by IGCP (3000 USD, minus wire-transfer and currency exchange fees), was used for the Annual IGCP641 Workshop in Alicante and the field trip to Murcia. About 40%, was used to allow the participation of an early career researcher from Pakistan (flight tickets). Detailed description is presented in ***Annex No. 1*** and in *Form III*)

8. What additional funding besides the IGCP seed funding has your project obtained thanks to the IGCP label? Please estimate the budget received for meetings, research or other and identify the source.

- Key Laboratory of Earth Fissure Geological Disaster, China Ministry of Land and Resources – approx 30'000 USD for the 2-year project (2017-2019) SOLMEF: Numerical Simulations Of large-scale Lab-Models to study Earth Fissures generation in subsiding basins (SOLMEF);
- Key Laboratory of Earth Fissure Geological Disaster, China Ministry of Land and Resources approx 65'000 USD for the 2-year project (2017-2018) Open 2D Simulation Code of Earth Fissures;
- Shanghai Geological Survey / Jiangsu Geological Survey - approx 5'000 USD (flight tickets and accommodation) for the participation to the 1st International Workshop on Earth Fissures (Nanjing) and the 1st International Workshop on Urban Geology (Shanghai);
- University of Alicante – approx 3'000 USD to held the 3rd Annual workshop of IGCP641;
- CENAPRED (National Center of Disaters) from Mexico – approx 160´000 USD supported the project for mapping fractures in Mexico City.

9. Did all project leaders and participants inform their respective IGCP/IUGS National Committees?

Did you as project leaders encourage all project participants to inform their respective IGCP/IUGS National Committees? Did you inform the IGCP/IUGS National Committees of the countries where you had activities this year?

In Mexico, there is not IGCP National Committee but UNESCO IGCP secretariat provided our IGCP project related information to the Mexico National Commission to UNESCO as well as Spanish National Commission to UNESCO and Mexican and Spanish Permanent Delegations where the IGCP project meeting has been organised jointly between Spanish and Mexican Scientists.

10. Attach any information you may consider relevant

Attachments:

Financial statement	(*Form III*)	☒
Meeting report(s)	(*Form IV*)	☒
Publication list	(*Annex No. 2*)	☒
Other		☒

Annex No. 1. Complementary Information,
Annex No. 3. The Land Subsidence International Initiative (LaSII). Proposal,
Annex No. 4. Newspaper notes on the fracture map of Mexico City