

Workshop Report to ESSAC

Reat-time Amphibic Monitoring & Borehole Observatories

Acronym: **RAMBO**

MAGELLAN WORKSHOP SERIES

CONVENERS:

Achim Kopf, MARUM, Bremen University, Germany

and

Pierre Henry, CEREGE, Aix-en-Provence, France

Main sponsor of the workshop



Life, Earth and Environmental Sciences (LESC)

Co-sponsor of the workshop



Deutsche Forschungsgemeinschaft

1. SUMMARY

Many geodynamic processes are associated with seismicity, slope instability or both, and much progress has been made recently to unravel the mechanisms governing them. Historical records show that S-Europe is particularly vulnerable to geohazards, mostly because of its complex tectonic setting in the collision zone between Africa and Eurasia. In prehistoric times, hazards manifested themselves by destruction of world wonders (e.g., Colossus of Rhodes 224BC, Pharos Lighthouse 365AD) or places such as Troy, Armageddon, to name just a few. At present, the Mediterranean Sea comprises approximately 46000 km of coastline with 160 million people living along it (plus an additional 135 million tourists each year, i.e. 30% of the global tourism). Geohazards pose a considerable risk to society in the circum-Mediterranean, and large cities (Istanbul, Athens, Nice, etc.) plus stretches where the economical loss is potentially huge (e.g. French Riviera, etc.). As a consequence, the understanding of episodic and equally highly infrequent nature of natural hazards has to be improved. The only means to shed light on the processes governing earthquakes and landslides are time series data to identify precursor phenomena to the events. They are particularly critical in the IODP and ICDP context, as is successfully shown in various projects.

The Magellan Workshop (WS) sponsored by the European Science Foundation and MARUM Research Centre, Bremen was entitled “*Real-time Amphibic Monitoring & Borehole Observatories*”. It was recently held in Bremen, Germany, on 14-16 October, 2010. The workshop objectives were to explore the following fields of long-term monitoring and observatory approaches:

- borehole coring, downhole measurements and geophysics as a component of observatory site survey (stress determination, characterise the earth beneath stations)
- shallow borehole monitoring for parameters that cannot be accessed by surface monitoring (e.g. piezometers [currently installed in Nice and Sea of Marmara])
- deep boreholes for *in situ* characterisation and monitoring of faults.

To maximise the benefit of such observatory data, an efficient network (including a real-time connection) is critical for using the resulting scientific data in early warning. A total of 20 dedicated scientists participated at the workshop, from nine European countries and USA (see section “*workshop participants*”). The expertise of the group spans a wide spectrum within and beyond geosciences. In addition, several of the participants have been (or are) leaders of scientific drilling expeditions, involved in IODP and ICDP proposals, and/or leaders or associates in ongoing EU projects.

About 50-60% of the meeting was devoted to presentations about IODP and ICDP projects, active and future drilling proposals related to the topic of the workshop, and the associated technology required to achieve the goals (stress measurements, observatories, ship status, new site survey sources). The second half of the meeting was devoted to discussions in the entire group as well as in break-out working groups; in addition, writing groups formed to formulate observatory strategies in areas of marine or continental drilling. Also, one new IODP proposal spun off from these discussions.

The deliverables of the workshop, as stated in the application, are: (1) a summary of the workshop results (to ESF and ESSAC/ECORD); (2) a new proposal to IODP in the Sea of Marmara, and (3) several smaller documents that sketch observatory strategies for e.g., Nice Slope Landslide drilling (IODP 748_full2), Alpine Fault continental drilling, etc. The WS participants refrained from writing an EU proposal within FP7 because the current call for “Real-time earthquake mitigation” seems to focus on research other than drilling (i.e. data acquisition and, foremost, risk assessment).

2. SCIENTIFIC CONTENT AND DISCUSSION OF THE EVENT

Scientific presentations

The scientific program is presented in chapter 4, and its presentations are briefly reviewed in this chapter.

Introduction

The first part of the WS focused on the overall goals and the structure of the event. The conveners gave the first presentations and summarised both the main objectives of RAMBO and the situation regarding the funding possibilities for some observatory projects within Europe (programs issued by the EC, ESF, national funding agencies as well as the two scientific drilling programs). The conveners point out that, in contrast to the earlier goal of condensing the ESF RAMBO WS achievements into an EU proposal for the upcoming Nov 16, 2010 deadline within FP7 theme *Environment* (see WS proposal to ESF), that the event should largely be used to find common ground as a marine-continental group and identify the most pressing needs both regionally and technologically. The EU call in question, and its Subactivity 6.1.3.1 on Real-time hazard assessment and mitigation, had been lobbied by a group of scientists that already benefited from a FP6 STREP project named SAFER (Seismic Early Warning for Europe, see <http://www.saferproject.net/>) very efficiently. Extensive telephone conversations and confidential exchanges led the conveners (and some participants) to believe that there is not much point in interfering with this community, which largely focuses on using geological and physical data for risk analysis, early warning, and infrastructural requirements. In essence, what the RAMBO group has in mind is one step ahead of SAFER, i.e. provide the most reliable, scientifically advanced measurement of seismic precursors in the deep Earth. Instead of running into a situation of competition, which most likely would turn out to be a lost battle from the beginning, it was actually tried to invite members of the SAFER group to the WS. Since this failed, there was a tentative consensus after the conveners' introductory talks that it might be wise to step back, wait for the SAFER successor project to be launched, and then answer subsequent calls by submission of regionally focused, scientifically challenging drilling and observatory projects later in FP7.

Presentations on regional aspects for RAMBO

After the *Introduction*, the second block of talks was truly amphibic and focused on the North Anatolian Fault (NAF) and Sea of Marmara (SoM), an earthquake-prone strike-slip fault system between the Mediterranean and Black Seas. Three colleagues from Turkey wrap up the state-of-the-art regarding the regional marine geology, seismic surveys and an observatory proposal recently submitted for national funding. In total, 3 stations with multiple instruments that monitor the Izmit Bay, Central Ridge and Western Ridge regions of the SoM are planned and would provide efficient means to gather time series data around the megacity of Istanbul (also a focus of the SAFER project) and other areas. The talks clearly laid out the wealth of existing data in the marine realm, hence paving the way for an IODP drilling approach. The fourth SoM talk focused on how such a drilling proposal for future submission may look like, and how the US group involved in SoM research could use Turkish and other data and proceed with a submission for the April 1, 2011 deadline.

Two talks further highlighted the emerging needs for research and hazard mitigation in the area. Results from a French-Turkish collaboration shed light on the active fluid flow, seismicity, and its interrelationship in the SoM. The session was complemented by the continental view on the area, where a mature ICDP proposal (GONAF – A deep Geophysical Observatory at the North Anatolian Fault) was introduced. The approach is somewhat amphibic since the two ICDP boreholes, 500 m each, are planned to be drilled from the

Princes Islands. Both an ICDP WS was held in the past and funds are available for drilling and installation of broadband seismometers. It was concluded that the groups involved in the various efforts on- and offshore need to work even more closely, and could aim for submission of a joint proposal in the future (see section on *Discussions* below).

The focus then changed towards other areas in the Mediterranean Sea. In a summary talk on EMSO and ESONET by one of the coordinators, a lot of information regarding the recently funded demonstration missions as well as future strategies was shared with the participants. The presentation tied the SoM (with SN-4 seafloor observatory installed during ESONET demo mission) to other areas in the Eastern and Western Mediterranean and Iberian Margin. From there, geohazard drilling and observatory projects got introduced and discussed. One of those focuses on landslides induced by a variety of triggers along the French Riviera, Ligurian Sea (IODP proposal 748-full2, Stegmann et al.). This project is currently viewed as one of the most challenging mission-specific drilling proposals and will benefit from a comprehensive observatory strategy (see *Discussions* section below). Two other talks provided overwhelming evidence for complex geohazardous processes related to fluid flow and seismicity in the Eastern Mediterranean. In the western Peloponnese, Greece, an attempt to launch the SEHELLARC project is planned. In there, the Cephalonia and Andravida strike-slip faults show immense seismic activity and also extrusion of tectonic units. A combined marine and land (i.e., islands of Killini, Pirgos, Zakynthos and Strophades) using seismometers and P transducers have proven powerful, and multi-parameter observations should focus on the Saronikos fault, not so far from the city of Athens. A second talk focused on EQ-triggered submarine seepage, pockmark structures, landslides, and other geohazards in the Corinth and Patras Gulf. Corinth in particular shows similarities to the Ligurian Margin (see above) in the sense that groundwater infiltrates the underground onshore and then is conducted to permeable layers that crop out along the submarine slope. There, they show larger activity around seismic events and cause prominent seepage and fresh water plumes in the water column. Both continental drilling (EU-funded drillhole CRLab1000; Cornet et al.) as well as IODP drilling (proposal by McNeill et al.) are already carried out or proposed into normal faults and other features in the Gulf of Corinth. The final regional talk went back to the continent, and namely into the Alto Tiberina normal fault, Central Italy. The MOLE project aims for both seismic monitoring and seismic hazard assessment, which seems particularly vital and timely after the historical destructions (1100, 1192, 1250, 1270, 1293) or the 1997 Umbria-Marche EQ. The drilling of a 2km pilot hole and a 5km main hole is mostly aiming at a comparison of the Alto Tiberina normal fault to strike slip- (SAFOD, NAF) or thrust faults (NanTroSEIZE, etc.), and in particular the role of CO₂ and other fluids involved.

Several of the presentations during the *RAMBO* WS are likely to develop into drilling proposals (if not already established), and may desirably to be turned into amphibious drilling projects, i.e. combined IODP and ICDP approaches. See details in the *Discussions* section below.

Presentations on generic technological requirements for RAMBO

In a third block of talks, state-of-the-art observatory components of crucial merit to the planned projects got introduced. Topics included everything from deep borehole instruments on- and offshore, shallow seafloor probes, and communication devices all the way to the home institutions (or policymakers in the case of early-warning-systems).

The most recent status of the Tsunami Early Warning System in the Indian Ocean was introduced by highlighting both the achievements and technical difficulties. Similarly, challenges of difficulties with respect to sensor compatibility, communication, power supply between various observatory systems. Examples included NEPTUNE and ESONET as well as borehole observatories. In the shallow marine subseafloor realm, a third talk described instruments operated by the leading European marine research institutions, and most specifically IFREMER France. It was explored how some of the achievements, e.g. by the

ASSEM project, can be transferred to some of the regional projects introduced in the earlier talks. The final two generic presentations focused entirely on deep borehole sensors and hazard monitoring, both in ocean and continental drilling. The history of CORK (Circulation Obviation Retrofit Kit) observatories was illuminated and the changes in design, both as a result of scientific requirements but also in the light of simplifying matters of these demanding engineering tasks and operations got introduced. CORK measurements include both strain, seismicity and hydraulic parameters, but could also provide access for sampling and active as well as passive experiments. The concluding talk introduced strain and seismicity in boreholes on land by nicely wrapping up 3 decades of experience in this field. The presentation was tailored to allow all WS participants to identify their own instrument setup for the geological setting they are most interested in. A "Gedankenexperiment" about a specific site in Europe challenged the participants' intellect and imagination and was a perfect stimulus for the upcoming discussions in the plenary session as well as in the break-out groups.

Discussions

During the second half of day 2, and also during day 3, we informally set up working groups in which the experts on technology mixed with those holding the regional expertise. Over the course of these discussions, people were changing from one group to the other, this way ensuring that information was effectively spread.

Working group 1: NAF/SoM (IODP, ICDP)

The participants from mostly Turkey, France and the US formed a break-out group that explored how to tie the existing plans for a seafloor observatory (to be funded by the Turkish government) and the achievements of the ESONET demonstration mission (Marmara-DM) in the area may be mated with boreholes by the IODP. A drilling proposal in the SoM was initially sketched by lead-PIs Cecilia McHugh and Pierre Henry with the help of the entire break-out group. The project comprises mission-specific drilling and conventional *Joides Resolution* drilling. Funding for a specific workshop will be requested to IODP. The sites will be selected based on a wealth of seismic data and seafloor surveys from cruises Seismarmara, Marmarascarp, Marnaut, Marmesonet, RV Urania-2009 and Piri Reis-2008 (Tamam) and Piri Reis-2010 cruises.

A proposal was eventually submitted to the FP7 call. The proposal MARQUAKE was coordinated by Louis Geli (Ifremer) and involves RAMBO workshop participants from ITU and CNRS. This submission is an important step in the planning of the seafloor observatory infrastructure in the SoM, stating the development of methods for the detection of crustal transients and their potential use for early warning as essential objectives, and including the Disaster and Emergency Management Presidency, a Turkish governmental organisation, as partner.

Working group 2: Ligurian Margin observatory (IODP)

A subgroup of the participants try to add a detailed observatory layout to the successful MSP drilling proposal 748 by Stegmann and others. The document ended up to be rather specific given that the exact locations and depths of the boreholes are known and provided that a proposal for large-scale national funding was recently submitted to the French government. It was concluded that a cable connection to land is mandatory for quasi-unlimited power supply and data transmission bandwidth, and this cable should have a hub for underwater-mateable connections in approx. 50 m water depth. From there, both seafloor instruments and borehole instrument packages could be distributed in the entire study area. For 2 of the 9 boreholes proposed, portable low-frequency spring seismometers are to be coupled to the stiffer, Upper Pliocene formation, possibly by cementing them into place. Strainmeters as well as hydrologic umbilicals for pore pressure monitoring and fluid sampling at multiple levels is proposed for 5 holes (2 in the landslide scar, 2 for reference adjacent to it, and one further downslope). Time series sampling of pore fluids is possible. All observatory information is to be handled by an

upgraded, COSTOF-type node as had been developed at IFREMER a while ago. Links to EMSO are established to fund part of the seafloor installation prerequisites.

Working group 3: Seismometer and hydrology in Alpine Fault borehole (ICDP)

In addition to the successful pre-proposal to ICDP (workshop held in 2008), three groups (NZ, UK, GER) gathered national funding to have two pilot holes drilled to appx. 300 m each prior to any ICDP operations. Drilling of these holes will take place near Gaunt Greek, most likely in Feb-Mar 2011. Given the unstable gravel layers in parts of the hangingwall section above the Alpine Fault, at least one of the holes will be stabilised with plastic casing liners, thus allowing the installation of instruments on a temporary or permanent basis. Based on pre-site surveys and surface outcrops, it looks as if the gouge in the fault zone is under- as well as overlain by permeable country rock. Thus, pore pressure monitoring is carried out in these zones as well as in the hangingwall and footwall sections. Thermistors are attached to the tubing and a set of 6 seismometers will be equally spaced over the borehole. The second hole will be kept free of installations in the beginning, and may later be equipped based on the results from the first hole. Together with earlier installations at SAFOD, TCDP, LVEW and BOOM at Basel, the borehole instrument packages may serve as a role model for the deeper drilling through the Alpine Fault planned in the framework of ICDP.

Working group 4: Buoy system for marine observatories (and TEWS)

The fourth group explored inexpensive ways in marine long-term monitoring without utilising cables and not necessarily involving drill holes. Such buoy systems could be used as stand-alone gear, fully self-contained, and could be transferred from one project to the other after completion of the first. The discussion focused around a high capacity power system, the high volume telemetry system, the instrument interface, etc.; in addition, the observatory could be a very visible demonstration field test for advanced instrument interface systems based on JDDAC, puck technology, etc.

In order to achieve the goals of technology sharing and technology transfer it is expected that an effort will be made to include relevant European industrial partners for appropriate components of the system, for example the vertical riser cable. It is further explored by scientists at MARUM whether a close collaboration with MBARI (USA) for development and knowhow transfer can be established.

In summary, discussions focused on funding and proactive steps to increase recognition of scientific drilling for an improved understanding of geohazards within individual member countries, EU and IODP/ICDP. Important points of discussion were:

- Build on IODP INVEST Bremen meeting and new (draft) Science Plan in order to formulate new proposals for Geohazard drilling, with a particular focus on societal needs and early warning.
- Assess the ability of individual scientists, or a *RAMBO* pressure group, to attract national grants, but also ESF and EU funding for IODP- and ICDP- related research.
- Pave the way for geohazards being a prominent part of the DS³F (Deep Sea & Sub-Seafloor Frontier) project, and similar initiatives, which inform the Marine Board and European Commission about research strategies for the next decade.
- Explore how to exploit industry-academia collaboration (including SME involvement) and possibilities within the EC's JPI (Joint Programming Initiative).
- Examine the position of the European Commission with regards to drilling, most importantly after the recent discussion of a drilling ban for the hydrocarbon industry in European waters.

These aspects will be tackled in Section 3 where light is shed on future strategies, emerging research objectives, and other aspects in the interest of the *RAMBO* group.

3. ASSESSMENT OF RESULTS AND IMPACT ON FUTURE DIRECTIONS IN THE FIELD

In order to place the results of the workshop into the context of larger initiatives and recognition of the expert group on real-time monitoring in the ocean, sub-seafloor, and continental settings, we trust the largest impact of the *RAMBO* workshop is to be anticipated for the ICDP and IODP. Several drilling proposals underway received significant input from the break-out group discussions. For ocean drilling, these were most prominently the Ligurian Margin and Sea of Marmara, and to a lesser extent the Hellenic Arc and Gulf of Corinth. On land, attention was largely given to the NAF and Alpine Fault. In each case, the ESF funding was vital and the most efficient means to make a big step forward with a number of key players in the field; without a dedicated workshop such as *RAMBO*, it would have been left pretty much to chance to have the right people meeting and discuss the aspects during other occasions such as conferences. Hence, we feel that the ESF funds were well invested and clearly help initiatives where Europeans lead or contribute significantly are boosted by the event.

When assessing the WS's outcome from a more generic point of view, it can be safely assumed that having had a gathering of experts on the technologies involved in real-time observatories on and in the seafloor created a lot of synergy. As an example, the Ligurian Margin landslide observatory, which is planned in conjunction with IODP mission-specific drilling of proposal 748-full2, a huge contribution from onshore seismologist Peter Malin or IFREMER scientist Patrice Woerther was made, both so far not affiliated with ocean drilling. This cross-fertilisation, which was similarly observed in the SoM/NAF group, would not have been possible without the initiative of ESF.

As another key outcome of the workshop, the participants discussed national and EU funding schemes. Although the *RAMBO* group decided not to follow up on the initial idea of submitting a proposal for a large-scale IP for the Nov. 16, 2010 deadline in FP7 theme Environment (but for a smaller proposal *MARQUAKE*; see above), a strong sense that proposals related to IODP research should be tied to an approach to acquire EU funding has arisen. Such a strategy to exploit the EU funding mechanisms on various levels may include:

1. Enhance lobbyism in Brussels and with the national representatives of the national funding agencies in Brussels (or even policymakers) for real-time observations of geohazards
2. Try to expand the ESFRI list to have real-time observatories (see Ostend declaration, where time series data have been mentioned as one of the three key goals in the future)
3. Find ways to have EU calls on topics which correspond to mature drilling proposals in IODP and ICDP so that co-funding from Brussels is achieved.
4. Nurturing and/or establishment of industry cooperations. For this, a small group was formed during an earlier ESF Magellan WS on "*Ocean drilling for seismic hazard in European geosystems*" (held in Luleå, Sweden by Maria Ask and Achim Kopf).

All the above points, and 3 and 4 in particular, require substantial funds which, realistically, cannot easily be provided by a national funding agency. Also, the approaches to be taken are intellectually challenging and hence best addressed by an international team. One of the key benefits of *RAMBO*, but also *ESONET/EMSO* and other initiatives, is the aim to provide compatibility between data formats and technical specifications of the observatory transducers and instruments. This way, technology can be utilised across borders and between the various member countries of the European Union, and beyond.

Finally, the *RAMBO* group decided to act as an entity in the future. It was felt that it would be vital to expand the efforts beyond the participants and, in a first step, share the achievements of the workshop with all those colleagues who were unable to attend (see Section 5 below). In addition, it would be vital to form a pressure group that connects to other initiatives, e.g. the

EU Coordination Action Deep-Sea & Sub-Seafloor Frontier (DS³F) where a new science plan for deep-sea research is currently sketched for the European Commission. This paper will serve as a guideline for FP8 calls for research project, and real-time observatories and geohazards should clearly play a crucial role. Other associated projects, currently underway, include EPOS, the Earth Plate Observing System (as part of the ESFRI list), whose coordinator, like in DS³F, is part of the *RAMBO* core group.

In summary, it can be safely stated that the ESF Workshop served to advance and condense strategies and detailed ideas concerning a number of international projects in the field of observatories to monitor geohazards. In addition to these immediate benefits, it is now the core groups challenge to take these ideas further and to a next level where large-scale funding, most likely by the EU plus maybe comingled funds from national agencies and foundations, will allow to realise some of those plans.

4. FINAL PROGRAM OF THE WORKSHOP

14.10.

9.00 – 9.30	Opening & Welcome of organisers and hosts (Director MARUM)
9.30 – 10.00	Introduction / Workshop goals (Kopf/Henry)
10.00 – 10.30	Discussion on upcoming EU call, etc.
10.30 – 11.00	Coffee break
11.00 – 11.20	Namik Cagatay: Coring results in the SoM: paleocanography and seismoturbidites
11.20 – 11.40	Gunay Cifci: HR seismics in the SoM (TAMAM, MARMESONET)
11.40 – 12.00	Naci Gorur: Marmara observatory project
12.30 – 13.00	Cecilia Mc Hugh: IODP Marmara drilling proposal
13.00 – 14.00	Lunch
14.00 – 14.30	Pierre Henry: NAF seismicity and fluid emission in the SoM
14.30 – 15.00	Marco Bohnhoff: GONAF (replaced by Jörn Lauterjung)
15.00 – 15.30	Laura Beranzoli: EMSO-ESONET
15.30 – 16.00	Coffee
16.00 – 16.30	Sylvia Stegmann/Pierre Henry/AchimKopf: Ligurian Margin Seismicity and Landslides
16.30 – 17.00	Joanna Papoulia: Seismic and Tsunami Risk Assessment in western Peloponnese, Greece
17.00 – 17.30	George Ferentinos: Corinth and Patras Gulf a Laboratory for Real Time Monitoring Earthquakes, Submarine landslides and Tsunami
17.30 – 18.00	Maria-Teresa Mariucci: The ICDP MOLE project
19.30 ff.	Social dinner: Outer Roads (Beluga Tower)

15.10.

9.00 – 10.30	Plenary discussion of individual IODP and ICDP projects and overlapping long-term monitoring goals
10.30 – 11.00	Coffee break
11.00 – 11.20	Jörn Lauterjung Challenges in real-time monitoring - TEWS
11.20 – 12.00	Patrice Woerther, Christoph Waldmann: Observatory systems: State-of-the-Art, Compatibility, Specifications
12.00 – 12.30	Demian Saffer: CORK observatories in IODP
12.30 – 13.00	Peter Malin: Seismometer arrays in SAFOD and elsewhere: Lessons learned
13.00 – 14.00	Lunch
14.00 – 17.00	Formation of working groups; Discussion on the development of (i) the observatory component active and planned drilling proposals, (ii) challenges in using time series data in real-time for early warning, (iii) planning how to fund some of the observatories in the near future (EU, national agencies, etc.)
17.00 – 17.30	Coffee
17.30 – 18.30	Report by working group leaders. Plenary discussion. End of seminar-style WS.

19.30 Joint dinner of remaining participants (to be discussed at the workshop)

16.10.

9.00 – 14.00 Informal discussion and writing of proposal drafts in working groups or sub-groups (re-arranged from Day 2 depending on discussion and funding opportunities), Collaborations and links to ongoing European activities; Exploitation of future calls by the EC (Joint Marine calls, thematic calls in ICT and ENV, etc.) and ESF (EuroCORES, etc.).

14.00 End of Workshop

5. WORKSHOP PARTICIPANTS

Funded workshop participants

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Guests during part of the workshop

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The following scientists were also contacted, but had to turn down the invitation owing to illness or other obligations:

Marco Nohnhoff, Georg Dresen (GER)

Paola Montone, Massimo Cocco, Luca Gasparini (IT)

Maarten Vanneste (N)

Maria Ask (SWE)

Eiichiro Araki, Yoshiyuki Kaneda (J)

Louis Geli, Nabil Sultan, Pierre Cochonat, Francois Cornet, Pierre Briole, Jaques Deverchere, Alfred Hirn, Anne Deschamps, Mathilde Cannat, Jean Francois Rolin (FR)

Torild van Eck, Gabriela Unterseh (NL)

Estela Esmerode (DK)

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Alastair Robertson, Lisa McNeill (UK)

Angelo Camerlenghi (ES)

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Karim Yelles (Algeria)